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# The Concept of the Geotourism Potential and Its Practical Application: A Case Study of the Prządki (the Spinners) Nature Reserve in the Carpathians, Poland

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**Abstract:** This paper reviews the recent use of the term “geotourism potential” in the scientific literature and proposes a new approach to the concept of geotourism potential. The concept assumes that every geotourism object has the well-developed features that allow one to learn and understand the object’s structure, genesis and properties. A method for the application of this concept to any geotourism object is proposed. The procedure and guidelines for the compilation of geotourism potential are applied on the example—the Prządki Nature Reserve in the Flysch Carpathians, Poland. Based on the field research, the research results of other scientists, and the internationally accepted definitions of terms connected with geotourism, a definition of geotourism potential is presented for the first time in academic literature. The main results emphasize that only clearly exposed features within the geotourism object relate to geotourism potential, while educational potential and tourist infrastructure are not to be identified with this potential. The inclusion of a new procedure for use in geotourism research provides a comprehensive approach to the inventory of geotourism objects and the educational use of abiotic elements of nature, as well as biotic and cultural aspects related to geoheritage. The presented model has practical application in the design of geoeducational materials.

**Keywords:** geotourism; geoeducation; geotourism object; natural protected area; Flysch Carpathians

## 1. Introduction

Geotourism, as a field of research, requires a clear description and coherent terminology. The scientific basis of this discipline has been developed since the 1990s, and now geotourism is referred to as the “modern geological paradigm” [1]. During last twenty years two approaches of geotourism have been developed—“the geological” approach [2–4] and “the geographical” one [5]—indicating that this field still requires conceptual work and clarification [6].

One such concept is geotourism potential, which is used by researchers and is most often mentioned during the assessment of geodiversity, geoheritage, and geological or geomorphological sites [7–10]. According to a comparative analysis of the literature, geotourism potential is one of the most frequently discussed topics of research in geotourism [11]. However, there is no definition of geotourism potential or its analysis, particularly for geotourism objects, which are the basic in situ objects made available for exploration as part of geotourism activities [12].

Most of the definitions of geotourism emphasize its cognitive role (i.e., education, learning, understanding, appreciation, etc., see the definitions of geotourism in Table 1 [13–30]; see also Table 1 in [3] and Table 1.1 in [1]), which is the starting point for the reflections in this article. Geoeducation and

methods of transferring geosciences to the public (geointerpretation) are some of the basic tasks in geotourism. Concepts such as “ABC geotourism” [31] and “3G’s geotourism” [3] underline the importance of geoeducation in geotourism and thus the significance of understanding geological processes for maintaining life on Earth, sustainable development, and preventing climate change. Considering the geological [2–4] and geographical [5,6,32] nature of geotourism, the method of compiling the geotourism potential presented in this article fits into both concepts of geotourism perception. The very process of compiling the potential for a geotourism object is consistent with the geological approach of the geotourism definitions, while the use of the results of such a compilation may serve the purposes specified by the geographical approach.

**Table 1.** Selected definitions and terms used in geotourism.

Term	Definition	Author
Geodiversity	The natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (land form, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems.	[13]
Geoheritage	Those elements of geodiversity, which have high scientific value and may be used for human purposes (other than resource exploitation, e.g., education, culture, tourism, recreation, leisure, etc.) with necessity of protection for present and future generations.	Based on: [13,14,19]
Geotourism	A form of natural area tourism that specifically focuses on landscape and geology. It promotes tourism to geosites and the conservation of the geodiversity and an understanding of Earth sciences, through appreciation and learning. This is achieved through independent visits to geological features, use of geo-trials and viewpoints, guided tours, geo-activities and patronage of geosites visitor centers.	[2]
	Geotourism is an offshoot of cognitive tourism and/or adventure tourism based upon visits to geological objects (geosites) and recognition of geological processes integrated with aesthetic experiences gained by the contact with a geosite.	Based on: [20,21]
	The provision of interpretative and service facilities for geosites and geomorphosites and their encompassing topography, together with their associated in situ and ex situ artefacts, to constituency-build for their conservation by generating appreciation, learning and research by and for current and future generations.	Based on: [3,4]
	An intentional learning about the Earth’s heritage and abiotic elements of the contemporary environment and those aspects of human activity that are directly related to the use of Earth’s resources.	[22]
	Geotourism allow tourists to know the local geology but also to better understand that this geology is closely related with all the other assets of the territory, such as biodiversity, archaeological and cultural values, gastronomy, etc.	[23]
Geo-interpretation	The art or science of determining and then communicating the meaning or significance of a geological or geomorphological phenomenon, event, or location.	[3]
Geoeducation	A discipline in the environmental education focused on abiotic nature that offer of direct contact with natural materials in their natural conditions, conscious familiarization with their properties and importance through stories and interpretations with emphasis on nontraditional forms of providing information.	Based on: [24]
Geotourism object	Any natural or cultural object, representing Earth sciences knowledge, which may generate tourism activity, after appropriate provision and promotion.	Based on: [12]
Geotourism product	Tangible and intangible products developed on the basis of abiotic nature, co-created (knowledge and craft) and experienced in connection with travel outside the place of residence, both before travel, during its duration, as well as during the geotourist’s stay and after their return, enabling the accomplishment of the geotourism purposes.	[25]
Tourist/tourism attraction	Things for the tourists to see and/or to do, services and facilities.	Based on: [26,27]
	An empirical relationship between a tourist, a sight, and a marker—a piece of information about a sight.	[28]
Geotourism attraction	Geotourism objects, areas, active geological and geomorphological processes and events that can be observed by people, together with appropriate development and geointerpretation that attract tourists to a specific place.	Own definition based on: [12,20]
Potential	The possibility of something happening or being developed or used. Qualities that exist and can be developed.	[29]
Tourism potential	The ability of a site to attract and receive tourists with concerns about accessibility, resource quality, interpretation of resources, and so on.	[30]
	The totality of natural, cultural, historical and socio-economic background for the organization of tourist activity in the particular area.	[30]

Therefore, the main reason for taking up this topic and developing the concept of geotourism potential is this concept’s usefulness in the implementation of the aforementioned tasks. Developing a model for compiling the geotourism potential of a single geotourism object or even whole areas will help design geoeducational materials and develop geotourism attractions and geotourism products.

The aim of the article is to propose a definition of geotourism potential and a model of geotourism potential compilation for a geotourism object understood as any natural or cultural object representing Earth sciences knowledge, which may generate tourism activity, after appropriate provision and promotion [12]. The model was tested on a selected geotourism object from the Carpathians (S Poland), a group of sandstone landforms within an inanimate nature reserve named “Prządki” (“the Spinners”). This territory is well known in the domestic scientific and geotourism literature [33–40], but detailed analyses and field studies on its geotourism potential will better facilitate the compilation and

complementation of data to develop geoeducational activities. Confirmation of the object's uniqueness was also possible along with the area's need for better exposure, protection, and geotourist access.

## 2. Geotourism Potential

### 2.1. Literature Review and Terminology

The term “geotourism potential” is used in scientific studies devoted to geotourism, geodiversity, geoheritage, and geoconservation [7–9,41–56]. These authors, in relation to various thematic frameworks and defined geographical and geological regions, present assessments and sets of geotourism potential acquired through various research methods, mainly through valorization [7,9,10,50]. The term “geotourism potential” is sometimes used in the titles of articles, without indicating which elements of the analysed object or area should be recognized to have such potential [9,10,41,42,44,45,47,54,55].

According to Dowling and Newsome [40], every place has geotourism potential, described as an area's dissimilarity from its surroundings and the individual geological history of a specific place.

Štrba [50] indicated, among other factors, the availability of tourist infrastructure as an element of geotourism potential. Recognized elements of geotourism potential include transport accessibility and tourism development [56], tourist availability, the presence of information panels and popular-science publications [48], the presence of educational products (e.g., maps, guidebooks, and guided tours), local products, and other crafts [7,57]. Sometimes the term is presented in two ways [56], as a set of inanimate natural and anthropogenically changed objects (natural rock forms, drifts, and post-mining excavations) or as specific features of the previously mentioned landscape elements (e.g., inactive quarries).

Kubalíková [8] identified geotourism potential using the criteria of assessment method. As a part of geotourism potential, Kubalíková includes the availability of products that support education, the level of accessibility and visibility of the site, the presence of tourist infrastructure, the existence of threats and risks, the range of conservation activities, and existing legislative protection of the site.

Solarska et al. [52] approached the issue differently, noting that the geotourism potential of the area includes features that are clearly exposed and readable not only for a group of specialists (e.g., geologists and geomorphologists) but also for every tourist, through both natural processes and man-made ones. Lubova et al. [49] expressed similar conclusions recognizing the geotourism potential of object features that attract the attention of a tourist (e.g., the size, shape, and impact on the local culture). Based on such features, the geology and formation of the object can be explained, as well as the scale, size, and chronology of the geological processes that led to its creation. The historical and present-day influence of the object on the shape of the local culture or beliefs can also be examined. A similar mode of understanding was presented by Górska-Zabielska [46], who accurately highlighted that the features of erratic boulders can generate tourist interest and, therefore, serve it can serve as a geoeducational resource [7].

As a summary of the concepts presented above, it is worth mentioning the research carried out by Štrba [53], which indicates that the most important factor for a tourist is the visual attractiveness of the geotourism object. A visitor will first visit the objects that attract his or her attention based on their shapes, colors or set of colors, and visible patterns, such as sedimentary structures.

As an important benefit of determining geotourism potential, researchers highlight the possibility of educational development. Assessment models of geotourism potential often include the criterion called “educational potential” (also, pedagogical, didactic, interpretative, etc.) (Table 1) for assessing the suitability of a given object for geoeducation [19,58–60].

Gray [8] emphasized that the assessment of educational values in an area can indicate the places of interest for students of Earth sciences studying phenomena occurring in nature. Furthermore, by observing the mining operations of mineral resources, children can be made aware of the important role of rocks in the economy of the region. A similar idea was promoted by UNESCO Global Geoparks [61]. As one of their priority tasks, UNESCO Global Geoparks highlighted the need to

educate all age groups about geological and mining heritage, its significance for the local cultural and incorporeal heritage, and links with emerging geohazards, as well as the effects of natural disasters.

Kubalíková and Kirchner [59] considered pedagogical potential as the main criteria of geosite and geomorphosite valorization. As components of this criterion, they considered the features of the object itself (i.e., readability, good feature formation, and visibility of geological and geomorphological processes) and the presence of products supporting education (e.g., leaflets, guided tours, maps, trails, information boards, and information centers). Štepišnik et al. [60] presented educational potential as a result of the valorization method, targeting a small but directly defined group of recipients (students). For them, the conformity of geotourism trip content with the core curriculum is important, as is the possibility of using geointerpretation techniques and making visited places accessible and safe during sightseeing.

An interesting combination of assessment criteria for the educational use of geosites was presented by Lima et al. [58], who proposed considering the “monumentality” feature. She also highlighted the importance of the readability of observed features and perceived the scope of educational potential as illustrative materials of geological features useful for all levels of education or only for a certain level, e.g., university. Hence, the conclusion is that the level of substantive advancement of the recipient determines whether a given geotourism object is suitable for his or her further education.

Brilha [19] also referred to the possibility of using geodiversity and geoheritage objects in geoeducational programs, emphasizing the importance of creating and implementing regional geoconservation strategies. Brilha indicated the need to assess objects and areas in terms of their geological diversity (Quantitative Assessment of Scientific Value), didactic potential (Quantitative Assessment of Potential Educational Use), and interpretative potential (Quantitative Assessment of Potential Touristic Use). According to the author, the implementation of a geoconservation strategy includes the interpretation and promotion of Earth’s heritage, which should be inventoried and assessed in a manner that strictly identifies the subject of the assessment (the topic), the set of values (the value), and the scale and the aim of valorization (the use) [58].

Therefore, authors’ perceptions of the term geotourism potential largely coincide with the semantic scope of the term “educational potential” (pedagogical, didactic, and interpretative) but also often refers to tourism infrastructure, tourist information, guide activities, and existing geoproducts.

## 2.2. The Concept and Definition of Geotourism Potential

Based on an analysis of the articles cited in the Section 2.1, the term “geotourism potential” is often used in the context of assessing its quality. However, it is worth clarifying what the concept of geotourism potential means; what types of elements, features, and values of a geotourism object comprise this potential; and for what purposes and by whom this potential can be used. This will be helpful in standardizing the terminology and better applying the values of geodiversity in geoeducation.

The definitions of the term geotourism proposed by various authors (Table 1) indicate the essence of geotourism (geological approach of the geotourism definition [6]): the form of tourism activity, the subject of interest, and the method of making a geotourism object available.

1. *The form of tourism* is classified as cognitive and is focused on gaining knowledge (cognition and understanding) about the visited objects, their observed features, and their ongoing geological processes [2,22,23]. It is motivated by the desire for aesthetic experiences while in contact with the beauty of nature [20,21]. The concept of geotourism as a form of tourism activity is aimed at a wide audience [3,4]; however, this concept uses the tourist’s targeted interests, which motivate people to practice sightseeing, as well as cognitive, active, and adventure tourism [20,21]. The receiver of a geotourism offer is a person interested in the surrounding world and focused on learning and understanding the processes taking place in it [2,5,23]. Creating geotourism attractions that will interest tourists requires, first of all, an analysis of the geotourism potential of a given object or area.

2. *The subject of interest* in geotourism is the landscape along with its structure and geological history, as well as individual geotourism objects [12], geological processes that can be observed, and material manifestations of human activity using the Earth's resources. However, the elements of geodiversity [13] and geoheritage (see the definitions in Table 1) are not equally attractive and worth exploring for a geotourist, whose attention will firstly be drawn to objects of high visual value with interesting shapes, colors, sizes, or intensity levels of the processes taking place [53]. Objects with a promoted, attractive, and innovative geointerpretation offer may also arouse his or her interest. As a form of tourism, geotourism—especially on a regional or national scale—should be based on such facilities. On the other hand, geotourism may be a tool for sustainable development by facilitating the high-quality development of geotourism objects of local importance, usually those that are less spectacular. Such objects located “in the neighborhood” with appropriate information facilities will be a valuable geoeducational tool, allowing one to understand the relationship between natural processes and human activities [23]. Regardless of the rank of a facility, it is necessary to develop its geotourism potential, the full or selected scope of which will be used in geoeducation.
3. *The method of making the object available* for geotourism should consider enabling tourist traffic [20,21], maintaining the presented geoheritage [2–4], and providing geointerpretation facilities and appropriate infrastructure that enables the acquisition of knowledge [3,4]. A willingness to learn, which motivates geotourists to be active, requires a way to make geotourism objects more accessible, so that, by exploring and using the object's values, knowledge can be conveyed in an innovative way and keep the geoheritage unchanged [3,4]. Geotourism, understood as area management, is implemented in this way. The necessity to equip a geotourism object with interpretative and service facilities for tourists is indicated by the various definitions of geotourism (Table 1) [2–4]. Such equipment includes a variety of geotourism products [25,57,62], such as geotourism trails and paths, geointerpretation panels, geoeducational centers, specialized geo-guide services, geotourism events, and the use of modern multimedia solutions. The creation of such products requires an analysis of the geotourism potential of a site (or area), and making these products available to the public helps to learn and understand the numerous inextricable relationships between the geological structure of the area, its shape, the features of its biodiversity, and its current cultural values [23,31]. Links between ill-considered human interference in ecosystems and disturbances are noteworthy, often leading to natural disasters [61] such as flooding, landslides, land subsidence, lowered levels of groundwater, etc. As a result, the awareness of local communities in the field of sustainable development policy increases, with care equally directed to the environment and humans (Table 1) [23].

Proper implementation of the activities within each of the above-mentioned issues is possible only after a thorough analysis of the geodiversity represented by a given geotourism object. The assessment of geotourism values, the geointerpretation of the Earth's heritage, and the creation of appropriate geoeducational tools are a subject of interest in geotourism developed as scientific research in geology [3,4]. Geography as an academic discipline also identifies and explains landscapes on the Earth's surface [57]. Scientists analyze and evaluate objects and areas in terms of their suitability for geotourism and geoeducation. The subject of their research is the overall geodiversity of the geotourism object upon which the designed research methods and tools are tested, and from which elements useful to geoeducation are selected.

Geotourism activity, completed and based on the above elements, can be realized by visiting a geotourism attraction (Table 1) [12,21]—that is, geotourism object [12]—with a specially developed geointerpretation [3], equipped with geoeducational materials and tourist infrastructure. Similarly, for tourists [26,27], a geotourism attraction is a material object that can be seen and/or an activity that can be performed independently thanks to a specially prepared tourist infrastructure. The only difference is the theme of the attraction, which, in the case of geotourism, is geology and landscape.

A geotourism attraction is created on the basis of a geotourism object [12] representing the Earth sciences, which may include, e.g., a geological outcrop, a river gorge, a waterfall, a cave, a quarry, or the aspects of the cultural geoheritage which are for example, stone in architecture, sites of mining heritage, cultivation site based on geomorphology. Each geotourism object has a certain resource of features—a “potential” [29]—allowing one to learn and understand its structure, genesis, and properties, which can be properly used in geoeducation. The features that comprise geotourism potential should be well-developed and understandable. Their interpretation should not raise any objections, and the tourist should be able to notice them on his or her own or with little help. The tourist should be informed about what a given feature is and why it developed this way through geoeducational materials available in the immediate vicinity of the facility.

The set of features that allows the object to be fully characterized, along with the indicated geoeducation topics, represents the geotourism potential, which is defined in this article as the abiotic features of a geotourism object and related biotic and cultural elements, whose good visibility attracts tourists’ attention and whose appropriate geointerpretation allows for geoeducation and generates an increase in tourist traffic.

The sense of geotourism as a form of cognitive tourism lies in the process of noticing and understanding the diversity of the geological structure, its genesis, and its impact on the surrounding biotic and cultural values (see the geotourism definitions in Table 1). Correctly compiled geotourism potential for a given geotourism object allows one to:

- Select the features/elements of the object that attracts the tourist’s attention;
- List the advantages of the object that may be interesting for a tourist;
- Compile the full range of educational topics that constitute the basis of geoeducation;
- Choose the scope of geoeducation suitable for different groups of receivers;
- Select geoeducation tools appropriate to the scope of the presented knowledge (e.g., an educational board, multimedia panel, smartphone application, field game, questing, etc.).

### 3. Method of Geotourism Potential Analysis

Based on the text in the Section 2.2, considerations concerning the meanings of the terms and concepts used in research studies on geotourism, a method for analyzing the geotourism potential for any object representing the geodiversity (in particular, for geotourism objects) was proposed.

This method was developed through workshops with students of the “Geotourism” specialization at the AGH University of Science and Technology [20] and involves the preparation of the scope of geointerpretation issues for any single geotourism object. Special attention is paid to the methodology of data compilation and gathering knowledge related to the geotourism object (not only in the field of geology), as well as organizing this knowledge, both in the literature and in the field. This proposal has a conceptual frame and can be used as a reference point for further consideration.

The geotourism potential analysis model consists of the following steps:

- Step 1: Collection of data about the object and its environment in the field of geosciences and supplementary sources (Table 2);
- Step 2: Organizing knowledge about the analysed object within categories, such as rocks, reliefs, bio- and geo-diversity interactions, and human and abiotic nature interactions (Table 2);
- Step 3: A field study of the geotourism object and its connection with the surroundings, involving:
  - (a) A selection of clear geological and geomorphological features of the object;
  - (b) Identification of features to be given direct attention (e.g., color, shape, smell, taste, texture, movement, sound, etc.) and linking them with knowledge in the field of Earth sciences;
  - (c) Establishment of relationships with biodiversity;
  - (d) Establishment of links with the local history, culture, folklore, etc.;
- Step 4: Compilation of geotourism potential elements according to the scheme (Table 4).

**Table 2.** Sources of literature used in geoeducation.

	Source of Literature		Categories of Geoeducation
Earth Sciences	Geology	e.g., mineralogy, petrography, sedimentology, paleontology, hydrogeology, tectonics etc.	Rock
	Geomorphology and Geography	e.g., relief, impact of the geology on relief, morphogenic processes, genesis of soils, climate etc.	Relief
Other Sciences	Biology	e.g., geology and ecology, biogeology, biogeography (relationship with species and minerals and rocks, impact of fauna and flora on the bedrock etc.)	Bio-geodiversity interactions
	Nature and environment protection	e.g., geoconservation, methods of nature protection, the impact of pollution on rocks, geohazards, climate changes, sustainability etc.	Human–abiotic nature interactions
	History, archaeology, ethnology etc.	e.g., mining heritage, stone in buildings, gems, masonry, geomorphology, sacred places, cultural landscape, history of sciences etc.	

**Table 3.** The scope of the geotourism potential for a geotourism object (<sup>1,2,3</sup> “ABC geotourism” concept by Dowling [31]: <sup>1</sup> A—abiotic, <sup>2</sup> B—biotic, <sup>3</sup> C—culture).

	The Identifiable Elements of Geotourism Potential		Examples of Geoeducation Issues
	by Scientist	by Tourist	
Rock <sup>1</sup>	Lithological features of rock/rock’s complex (e.g., granite, sandstone, marble)	rock: color, taste, smell, other features of the rock	<ul style="list-style-type: none"> <li>• variety of rocks, genesis, age</li> <li>• geological processes: e.g., diagenesis, cementation</li> </ul>
		rock components: colours, texture, structure	<ul style="list-style-type: none"> <li>• types of mineral/grain structures and textures</li> <li>• determination of mineral and grain composition</li> <li>• characterization of minerals and other rock components</li> <li>• the genesis of non-sedimentary structures and textures</li> <li>• mineral and other rock components features: e.g., rounding, sorting; types of cement/binder</li> <li>• grain transport (transport length, grain resistance to abrasion), porosity, fractions</li> </ul>
	Sedimentary structures (depositional, deformational, erosional, biogenic)	ornaments, patterns, color differences on the surface of the rock	<ul style="list-style-type: none"> <li>• types of sedimentary structures</li> <li>• genesis of sedimentary structures</li> <li>• mechanisms responsible for the formation of visible structures, e.g., turbidity currents, debris flow</li> <li>• environments of sedimentation</li> <li>• syndepositional processes, post-depositional processes</li> </ul>
			<ul style="list-style-type: none"> <li>• orogenic processes, their age</li> <li>• plate tectonics</li> <li>• mechanisms of tectonic processes</li> <li>• types and genesis of elements of tectonics (nappes, slices, folds, synclines, anticlines, faults, etc.)</li> <li>• types of joints, e.g., diagenetic, tectonic</li> </ul>
	Elements of tectonic (jointing, fault, fold, anticline, syncline, bed inclination etc.)	cracks, crevices, curves, inclination of rock layers	<ul style="list-style-type: none"> <li>• type, age of organisms</li> <li>• the appearance of organisms, life processes</li> <li>• characteristics of the living environment (and formation of rocks)</li> </ul>
Fossils (shells, bones, casts, trace fossils, organic hieroglyphs, burrows, petrified wood etc.)	remains and imprints of organisms	<ul style="list-style-type: none"> <li>• guide fossils</li> <li>• history of life and evolution</li> </ul>	

Table 3. Cont.

The Identifiable Elements of Geotourism Potential		Examples of Geoeducation Issues	
by Scientist	by Tourist		
Relief <sup>1</sup>	Landforms (tor, waterfall, cave, boulder field, spring, lake, river valley, gorge, cliff, dump etc.)	shape, size of the object, terrain morphology, landscape, panorama	<ul style="list-style-type: none"> <li>genesis and age of the form, genesis of surrounded landscape</li> <li>types of weathering processes that led to the creation of the form</li> <li>mechanisms of weathering/erosion/denudation processes, etc.</li> <li>impact of lithology, sedimentation, tectonic structures on the rocky form shape</li> <li>selective weathering—difference in rock resistance</li> </ul>
	Weathering/erosional forms	irregularity imprints, hollows on the surface of the rock	<ul style="list-style-type: none"> <li>types of erosional forms</li> <li>types of weathering structures (cellular, bowl, arcade structures, exfoliation areas, weathering ferricrust, pseudokarren, races of mud balls, weathering pits etc.)</li> <li>genesis and age of particular forms and structures</li> </ul>
	Active geological processes	e.g., movement, sound	<ul style="list-style-type: none"> <li>e.g., gas exhalation, geyser or volcano eruption, water movement</li> </ul>
Bio-geodiversity interactions <sup>2</sup>	Fauna and flora, Ecosystems, Biological weathering	vegetation (e.g., the presence of multi-coloured mosses, lichens, roots in rock crevasses, bird nests in loose settlements)	<ul style="list-style-type: none"> <li>influence of bedrock and morphology on the distribution of fauna and flora</li> <li>the impact of geological processes on the presence of specific species</li> <li>the course and impact of bioerosion on the condition of geological objects</li> <li>(mechanical weathering, chemical weathering)</li> <li>the impact of mining activity on the creation of new ecosystems</li> <li>presence of live fossils</li> </ul>
Human–Abiotic Nature Interactions <sup>3</sup>	History of science (lithostratigraphic name, scientific connections)	unknown scientific term given on information panel, guidebook, folder, tourist or sightseeing leaflet	<ul style="list-style-type: none"> <li>the significance of the names of geological units, rock formations, rock beds, layers</li> <li>locus typicus, stratotype</li> <li>scientific background for age of rocks definition</li> </ul>
	Folk and cultural connections	intriguing names and pictures, old beliefs and myths presented on the field	<ul style="list-style-type: none"> <li>geomythology</li> <li>links with the history of the region</li> <li>connections with famous persons, historical characters</li> <li>artistic inspirations in painting, decorative and applied art</li> <li>history of tourist movement e.g., engraving on rocks, historical tourist guides</li> </ul>
	Traces of exploitation, Economic exploitation of geodiversity	shapes, marks, regular voids/holes, irregularity of rock surfaces, irregularity of the ground	<ul style="list-style-type: none"> <li>rock properties determining its use in masonry</li> <li>operating methods and tools</li> <li>history of exploitation and local use of the raw material</li> <li>economic use of geodiversity/geoheritage (e.g., stone in architecture, building materials, energy production, industry, decorations, cultivation on specific ground, etc.)</li> <li>ways for the reclamation of a post-mining area</li> </ul>
	Geoconservation (legal geoconservation, active geoconservation, geohazards)	recognizable dangers (e.g., peeling rocks, slippery, sliding ground, cracks on the walls of the building)	<ul style="list-style-type: none"> <li>types and genesis of observed natural processes</li> <li>ways to counteraction and prevention</li> <li>consequences of improper local and global human activities</li> <li>the essence and legitimacy of sustainable development</li> </ul>
		discoloration, paintings on the rock surface, effects of rock climbing, devastation of dripstones and mudslides in caves, littering, wild exploitation of natural resources, improper development	<ul style="list-style-type: none"> <li>the genesis of destructive processes</li> <li>types and effects of improper human activity</li> <li>ways to counteraction and prevention</li> <li>human activity and climate changes</li> </ul>
	information boards, entry bans, tourist infrastructure (litter bins, sheds, shelters, handrails, pathways), protective treatments	<ul style="list-style-type: none"> <li>the legitimacy of establishing protection</li> <li>subject of protection</li> <li>protecting entity</li> <li>protection methods</li> <li>other types of national forms of protection</li> <li>alternative protection options</li> </ul>	

While the scope of Earth sciences is clear, the supplementary sources should be understood as sources whose information is related directly or indirectly to geological heritage, including geo-ecology, mining heritage, stone in architecture, geomythology, etc. Therefore, a more detailed analysis of the non-geological literature is needed, in which the geologist may recognize the impact of geodiversity on biodiversity, the locations and natures of settlements, local architecture and construction, industrial development based on local raw materials, unique customs, local folklore, etc. Such data will

often determine the uniqueness of the place and the importance of the local geology to regional development [63].

The classification of geotourism potential elements into four thematic groups is conditioned by the main tasks of geotourism—geoeducation and its addressee, the tourist. A similar division of environmental elements, developed for defining the term “geotourism”, was proposed by Dowling [31] as “ABC geotourism”, based on the abiotic, biotic, and cultural (ABC) components of the environment.

The division of abiotic features of a geotourism object into “rock” and “relief” elements results from the need to skilfully distinguish the stages of features’ origins, such as the formation of rocks and landforms. This is also reflected in the nomenclature of geological objects, e.g., “geosites” and “geomorphosites”, where the second type is distinguished as a type of geotourism object due to the great importance of its geomorphological features in the description of geoheritage [64]. Inanimate elements of nature such as climate, water, and soil are also included in the proposed statement but as factors generating specific natural processes whose effects we can observe.

The distinction between living natural elements and cultural elements of geoheritage allows us to better understand the significance of geological processes for life on the Earth and for humans and the places where they live. The easiest way to understand geology is to refer to facts, objects, activities, etc., known in everyday life. The artificial exposure of rocks in an abandoned quarry has greater value if the possibility exists to demonstrate the use of the raw material in the vicinity, e.g., as stone used in local building construction. These are elements of the “sense of place” [31,65], “value of geodiversity” [13], “geocultural heritage” [66], and “ethnogeology” [67]. It is equally important to highlight the relationship between geodiversity and biodiversity [68–71].

In general, the geotourist can be any person, regardless of their level of education or age. Therefore, to facilitate the understanding of geological processes, the most reasonable choice is to use the elements of geodiversity that attract tourists’ attention and are easily recognizable (with a little help from a guide, indicating elements for detailed observation). A tourist is usually a person without geological knowledge, so his or her perception of the environment is conditioned firstly by visual attractiveness—i.e., the perception of interesting shapes, color differences, or textures on the rocks [53]. The identification of a geodiversity site can be done using other senses (smell, taste, touch, and sound), which also affect the perception of the environment. Such an understanding of tourists’ perceptions is based on several years of didactic experience with students’ field classes, and also with interviews with tourists carried out during geological field works.

The thematic scope of geoeducation issues is thus proposed (Table 4) based on designating the most legible abiotic elements of the geotourism object and its immediate surroundings (rocks and morphology) the easiest to observe (color, shape, etc.) for the recipients—both scientists and tourists.

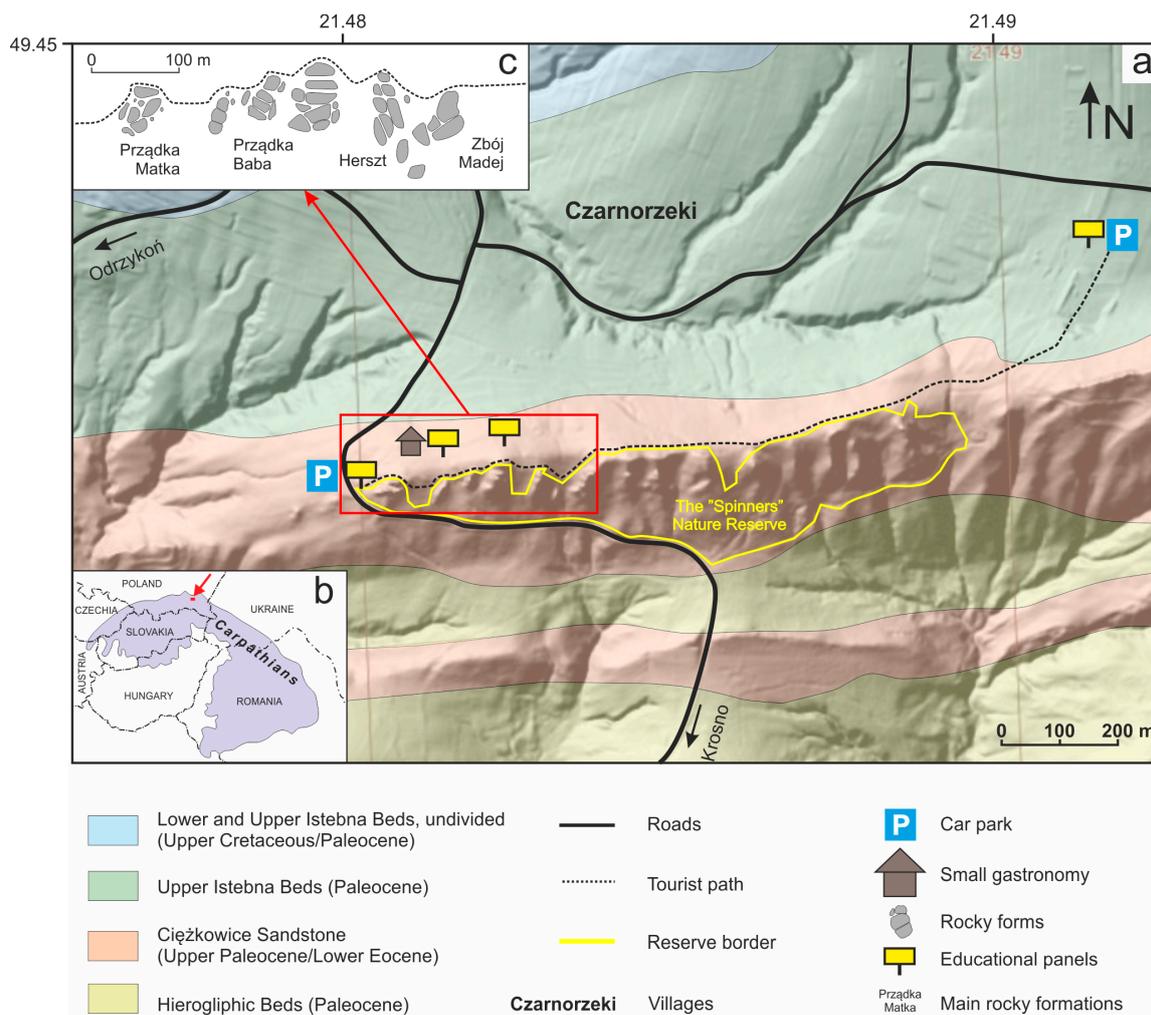
#### 4. Results

To highlight the accuracy of the geotourism potential definition and demonstrate the practical analytical application of this method, geotourism potential was compiled for a selected geotourism object, the Prządki (the Spinners) Nature Reserve (geological reserve). The steps and scheme for geotourism potential compilation provided in Table 4 are used. The group of sandstone rock formations is perceived as one of the most important tourist attractions of the Podkarpace Voivodship [39]. The scheme of the reserve description, presented below and the Table 4, are a consequence of using the “step 3” and “step 4” of the method of geotourism potential compilation.

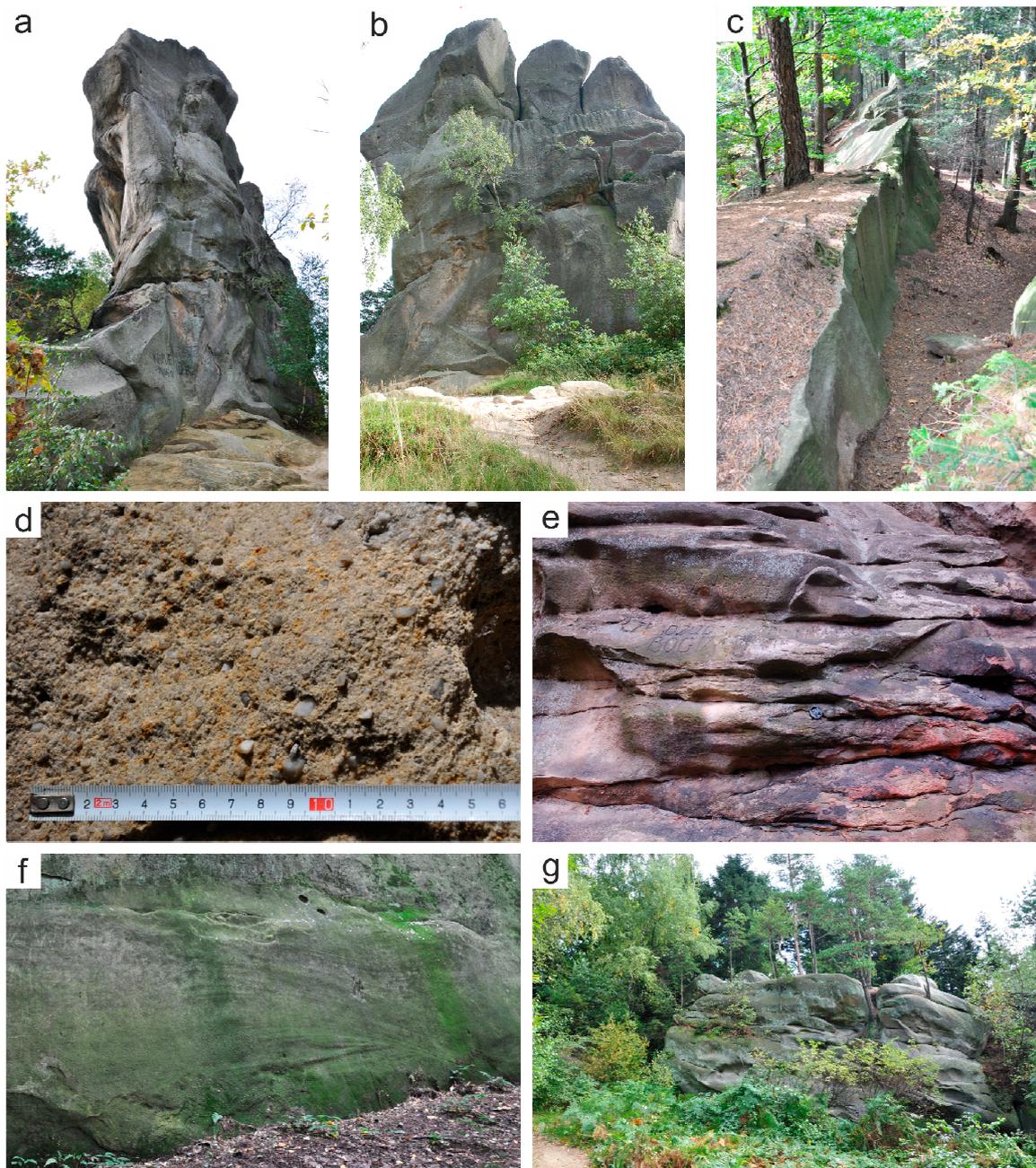
##### 4.1. Characteristic of the “Prządki” Nature Reserve as a Geotourism Object

The Prządki Nature Reserve, named after Professor Henryk Świdziński (with an area of 13.28 ha, established in 1957), is located in southern-east Poland on the Carpathian Foothills (Figure 1) [34,72,73] within the Czarnorzeki–Strzyżów Landscape Park. In the zone of the Prządki range, at a length of about 1 km, 14 groups of sandstone tors can be observed, in addition to isolated tors [74], with a height of up to 20 m. The highest tors are located in the northern zone of the reserve (on the ridge),

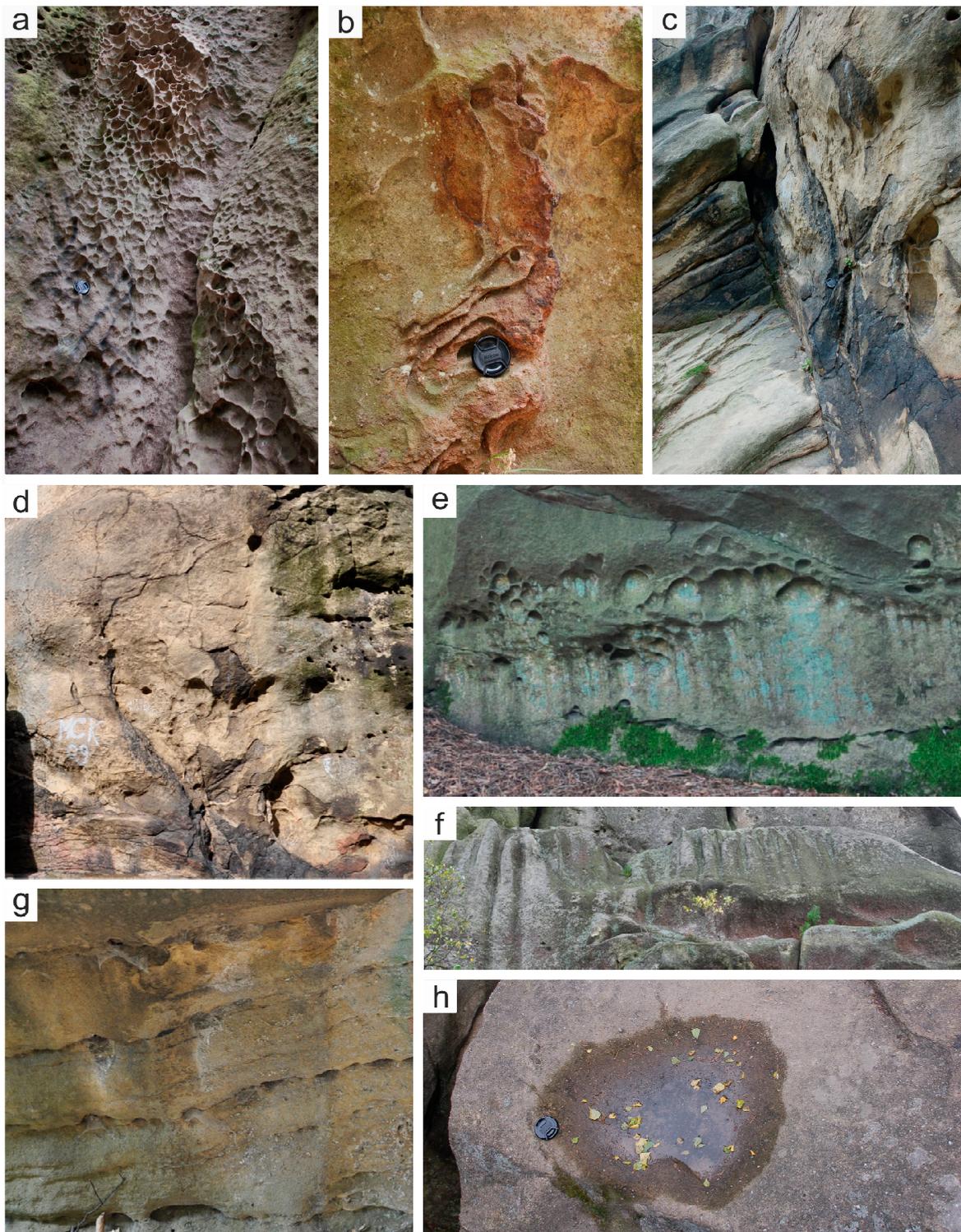
while on the southern slope, rock formations take on forms of various sizes and are often fragmented, wide, flat blocks that slowly slide down gravitationally on the slope [23]. Within the groups of tors, a narrow corridor has developed along the cracks. Due to weathering and erosion processes, four groups of sandstone rocks adopted interesting shapes, resulting in the fanciful names given to them, such as Prządka-Matka (Spinner-Mother), Prządka-Baba (Spinner-Woman), Herszt (Leader of the Gang), and Zbój Madej (Robber Madej) [74]. Due to the geoheritage of the area, a nature reserve project was created as early as the 1930s [75,76], and in 2006, the reserve itself was included on the list of supra-regional geosites of Poland, proposed for the international database of geosites—Global Geosites Program [37].



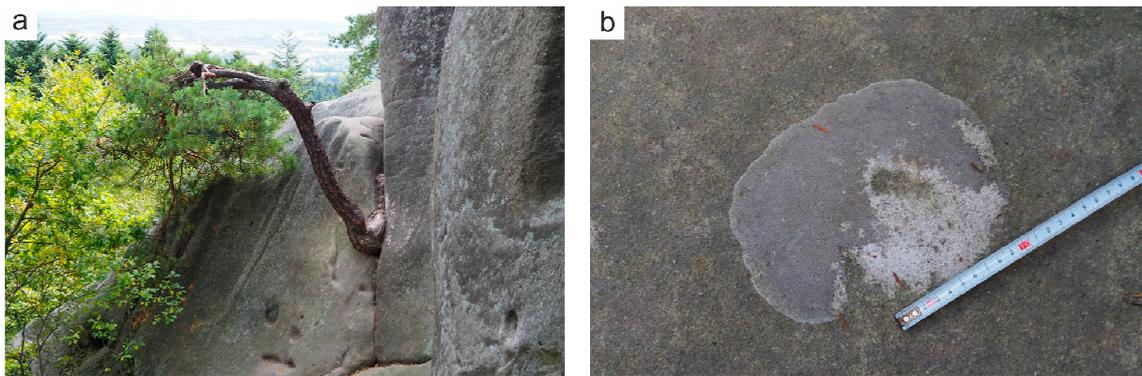
**Figure 1.** Geological sketch of the Prządki Nature Reserve area (a), its location in the Carpathian range (b) [72] and the arrangement of the main groups of sandstone tors [34] (c). Shaded relief based on WMS web service by the Head Office of Geodesy and Cartography [73].



**Figure 2.** Sandstone–conglomerate rocky formations in the area of the Prządki Nature Reserve: (a) tor of the Prządka–Matka complex; (b) the Prządka–Baba rocky tower; (c) a rocky ridge anthropogenically altered during stone exploitation; (d) pebbles of quartz inside the coarse-grained conglomerate layer of Ciężkowice Sandstone; (e) layers of medium-grained Ciężkowice Sandstone emphasized by weathering processes, with weathering ferricrust visible on the right; (f) a thick layer of fine and close-grained Ciężkowice Sandstone with an amalgamation on the top. Two traces (holes) of mud balls above the amalgamation. Sedimentary structures visible in the center part of the layer with parallel and diagonal lamination; (g) biogenic erosion. Photos by Welc and Miśkiewicz.



**Figure 3.** Weathering structures visible on the Ciężkowice Sandstone surface in the area of the Prządki Nature Reserve: (a) cellular structure of a honeycomb type; (b) thin weathering ferricrust of secondary cementation; (c) dark-grey limonite crust and areas of exfoliation; (d) areas of exfoliation; (e) possible bowl structures; (f) vertical pseudokarren type forms; (g) arcade structures developed along the bedding surface; (h) weathering pit infilled by water, developed on the top surface of the sandstone tor. Photos by Welc and Miśkiewicz.



**Figure 4.** Examples of biogenic erosion affecting the disintegration of rocks in the Prządki Nature Reserve: (a) mechanical weathering caused by tree roots growing in crevices and crushing rocks; (b) chemical weathering caused by the influence of aggressive chemical and organic compounds produced by organisms. Photos by Welc and Miśkiewicz.

#### 4.1.1. Rocks and Relief

The elevation featuring the Prządki Nature Reserve area is located on the southern limb of the Czarnorzeki–Węglówka Fold, formed within the eastern part of the Silesian Nappe, Outer Carpathians [74]. From the south, one can observe (Figure 1) a sandstone-shale complex of Hieroglyphic beds, very thick, massive Ciężkowice Sandstone, sub-divided by intervals of variegated shales and shales of the Upper Istebna Beds. The beds dip ca. 40° to the south. The ridge of the Prządki elevation was formed from the Ciężkowice Sandstone with a thickness of about 60 m and an Upper Paleocene/Lower Eocene age (about 60–50 Ma). The result of this geological structure is the present morphology of the Prządki elevation. The highest monadnocks (Figure 2a,b) are exposed to the surroundings due to the greater resistance of sandstones and conglomerates to erosion than the shale rocks adjacent to them in the south and north. The tors are formed within very thick and massive (without clearly visible lamination and gradation) sandstones and conglomerates (Figure 2c,d), occurring without mudstone shale intercalations (amalgamation present). Their grain material is poorly sorted, medium rounded, and accompanied by clayey–muddy cement, with iron rich compounds manifested by thin weathering ferricrust (Figure 2e) on the sandstone surface. For mineral composition, detritic quartz predominates over feldspar detritus, flakes of muscovite, and clasts of igneous and metamorphic rocks. The conglomerate parts contain randomly dispersed pebbles, mainly quartz grains (Figure 2d) with diameters of 1–2 cm [34–36,74,77].

The sandstone and conglomerate deposits of Ciężkowice Sandstone represent sediments and sedimentation mechanisms (sedimentary processes) typical for the Flysch Carpathians. These deposits, together with the mudstone interbeds, constitute flysch that was deposited into the deep-sea environment via sediment gravity flows [78]. In case of the sandstones and conglomerates of the Prządki Nature Reserve area it was coarse-clastic sediment accumulation within the sea basin (so called the Silesian Basin), taking place on its slope and at the foot of the slope. This flysch sedimentation type was interpreted as deposition within the deep-marine fan system [79] in the form of the main channel filling with sediments from high-density turbidity currents [80], whose deposits are called fluxoturbidites [81,82]. Similar siliciclastic deposits with such lithological–sedimentological feature development (coarse-grained, thick-bedded, massive, and amalgamated) are interpreted alternatively as the result of deposition within a deep-sea apron system [83] in the form of clastic tongues through sandy-to-gravelly debris flows and are called debrites [84].

**Table 4.** The scope of geotourism potential for the Prządki Nature Reserve, Polish Flysch, Carpathians. Based on [39]. (<sup>1,2,3</sup> “ABC geotourism” concept by Dowling [31]: <sup>1</sup> A—abiotic, <sup>2</sup> B—biotic, <sup>3</sup> C—culture).

The Identifiable Elements of Geotourism Potential		Examples of Geoeducation Issues	
by Scientist	by Tourist		
Rock <sup>1</sup>	Sandstone & Conglomerate (Figures 1 and 2d,e)	<ul style="list-style-type: none"> <li>different character of rocks surfaces</li> <li>different color of grains, (grey, white, black, silvery)</li> <li>grains of various sizes and shapes, round, angular</li> <li>grains get stuck together (cemented); parts of rock surfaces hard, solid and concise; other parts weathered and spilled (possible reaction with HCl)</li> </ul>	<ul style="list-style-type: none"> <li>genetic varieties of rocks: types of sedimentary detrital rocks</li> <li>mineral composition—among others: quartz, alkaline feldspar, biotite, muscovite;</li> <li>features of minerals</li> <li>terms of texture and structure of clastic sedimentary rock;</li> <li>grain transport (transport length, grain resistance to abrasion);</li> <li>grain features: e.g., rounding, sorting</li> <li>types of cement: e.g., silica-carbonate, silica-ferrous;</li> <li>porosity, fractions;</li> <li>geological processes, e.g., diagenesis, cementation</li> </ul>
	Sedimentary structures parallel lamination, diagonal lamination, normal graded bedding, channels, amalgamation, holes, traces of mud balls (Figure 2e,f)	<ul style="list-style-type: none"> <li>grain arrangement: chaotic, parallel, oblique; change in the grain size within the layer;</li> <li>different thicknesses of rock layers; spherical depressions, voids, holes</li> </ul>	<ul style="list-style-type: none"> <li>types of sedimentary structures (depositional, deformative, erosive, biogenic);</li> <li>mechanisms responsible for the emergence of visible structures, e.g., turbidity currents, debris flow;</li> <li>sedimentation environment: deep-sea sedimentation (flysch), submarine fans;</li> <li>syndepositional processes (during deposition), post-depositional processes (after deposition)</li> </ul>
	Compilation of Elements of the Geotourism	cracks, crevices	<ul style="list-style-type: none"> <li>types of joints and their genesis, e.g., diagenetic, tectonic;</li> <li>tectonic processes generated by orogenic movements of the Carpathians, formation of nappes, Alpine Orogeny</li> </ul>
	Landforms tor, rock mushroom, rocky ridge, rock pulpit, rock tower (Figure 2a–c,g)	rocks of various shapes	<ul style="list-style-type: none"> <li>landform processes: e.g., denudation, erosion, weathering;</li> <li>impact of lithology, sedimentary and tectonic structures on the shape of rock forms;</li> <li>selective weathering—difference in rock resistance;</li> <li>types of weathering processes and their mechanism (e.g., corrosion, frost weathering, insolation weathering, suffosion);</li> <li>microrelief, genesis of individual weathering forms, selective weathering;</li> <li>mass movements, e.g., falls, landslides, creep, ground subsidence;</li> <li>climate change, glaciation, periglacial climate</li> </ul>
Relief <sup>1</sup>	Weathering forms cellular, bowl, arcade structures, weathering pits, traces of mud balls, pseudo-karren crests, exfoliation surfaces, weathering ferricrust (Figures 2e and 3a–h)	<ul style="list-style-type: none"> <li>cavities of various sizes and concentrations;</li> <li>arcades, vertically developed grooves, brownish and dark-grey discoloration, layer detachment, incrustation</li> </ul>	

Table 4. Cont.

The Identifiable Elements of Geotourism Potential			Examples of Geoeducation Issues
by Scientist		by Tourist	
Bio-geodiversity interactions <sup>2</sup>	Fauna and flora, Ecosystems, Biological weathering (Figures 2g and 4a,b)	mosses and lichens on rock surfaces, species diversity of trees	<ul style="list-style-type: none"> <li>• Cieężkowie Sandstone as a good substrate for certain plant species, e.g., mosses and lichens on the surface of rocks, vegetation in rock crevices, direct sunlight or shade places, wet or dry;</li> <li>• characteristics of the forest ecosystem surrounding the rock formations;</li> <li>• mechanical weathering: e.g., widening of rock fractures by tree roots;</li> <li>• chemical weathering; e.g., the impact of aggressive chemical and organic compounds that are the product of the life activity of organisms</li> </ul>
Human–abiotic nature interactions <sup>3</sup>	History of science lithostratigraphic name, scientific connections (Figures 1 and 7c,d)	information panel in the reserve, scientific term mentioned	<ul style="list-style-type: none"> <li>• Cieężkowie Sandstone: meaning of the lithostratigraphic name;</li> <li>• stratigraphic issue;</li> <li>• age issue;</li> <li>• prof. Henryk Świdziński as a researcher and promoter of the Carpathian sandstone rocky forms’ protection</li> </ul>
	Folk and cultural connections (Figures 1 and 2a,b)	information panel in nature reserve, folk names of individual tors	<ul style="list-style-type: none"> <li>• names of rocky forms: Prządka–Matka, Prządka–Baba, Herszt, Zbój Madej;</li> <li>• geomorphology: local legends—a mythical explanation of the rock’s origin;</li> <li>• history of tourist movement in Prządki: historical tourist guides, engraving on rocks, lithographs, painting, poetry and romantic literature</li> </ul>
	Traces of exploitation, Economic exploitation of geodiversity (Figure 6a)	regular equal rows of stonework openings; surfaces of rock sides splitting; engraved stonemason inscriptions	<ul style="list-style-type: none"> <li>• rock properties determining its use in architecture;</li> <li>• methods and tools of exploitation, e.g., marks wedges and detaching rock;</li> <li>• history of exploitation and local use of the raw material, e.g., Kamieniec Castle in Odrzykoń village</li> </ul>

Table 4. Cont.

The Identifiable Elements of Geotourism Potential		Examples of Geoeducation Issues
by Scientist	by Tourist	
Human–abiotic nature interactions <sup>3</sup>		<ul style="list-style-type: none"> <li>• characteristics and effects of glaciations, periglacial climate;</li> <li>• types of mass-movements (e.g., rockfalls, landslides, down creeping);</li> <li>• gravitational settling of rocky forms on a basement made of ductile slates, the effect of gravitational settling;</li> <li>• geological processes causing natural hazards for tourists and methods of prevention</li> </ul>
	Geoconservation legal geoconservation, active geoconservation, geohazards (Figures 1, 6b–d and 7a–d)	<ul style="list-style-type: none"> <li>• destructive impact of overgrowing vegetation, littering, devastation of rocks (e.g., climbing, graffiti);</li> <li>• destructive impact of wild paths;</li> <li>• active protection: prohibition of exploitation and sampling of the rock, the designation of alternative teaching geo-points, removal of vegetation, cleaning, prohibition of climbing, marking tourist paths, installation of barriers and information infrastructure, ecological education geological processes causing natural hazards for tourists, warning boards;</li> <li>• methods of protection: prohibition of climbing, exploitation, sampling, movement outside designated paths; marking of tourist paths; repurchase of private land</li> </ul>
		<ul style="list-style-type: none"> <li>• rules for selecting the scope of tourist and geotourist information presented at the facility;</li> <li>• forms of nature protection (here: nature reserve);</li> <li>• types of types of nature reserves (here: geological reserve);</li> <li>• rules for establishing of nature reserve;</li> <li>• the meaning of conservation plan, entities responsible for the development and implementation of the plan;</li> <li>• the meaning of the Global Geosites Program, justification of high scientific and didactic value, unique group of sandstone rocky form in the Carpathians;</li> <li>• rules and possibilities of tourism infrastructure development in the area of the nature reserve</li> </ul>

The gravitational flows of sediment transporting clastic materials within the sedimentation basin are characterized by variable dynamics and various mechanisms of deposition. This enabled the origin of sedimentary structures, which can be observed today on the sandstone surfaces of the Prządki Nature Reserve rock complex [74]. The depositional structures are visible, such as the bedding (Figure 2e), parallel and diagonal lamination (Figure 2f), and normal graded bedding. Erosional structures of a channels type can be observed as well as amalgamation (Figure 2f) formed by the erosion of loose sediment deposited on the bottom of the reservoir [85–88].

Sediments originally deposited within the Silesian basin, together with the sediments of the other basins, were uplifted during the tectonic movements (late Miocene; about 12–7 Ma), detached from their substratum, and pushed northward, forming folded nappes, oriented one over the other [36]. The eastern part of the so-called Silesian Unit (to the east of the Dunajec river) is characterized by a folded structure, and the Prządki Nature Reserve is located on a hill constituting the southern limb of one of such folds.

After a period of increased tectonic movements, the discussed area was remodeled by an intense denudation processes—peneplanated with gradual reduction of the surface (Pliocene/Pleistocene). The weathering processes were especially intensive because of the periglacial climate of the glaciation period (Pleistocene, 2.58–0.11 Ma), and as a result the most resistant parts of the Cieżkowice Sandstone weathered. The fancifully shaped rocky forms of the Prządki Nature Reserve are monadnock elements (Figure 3a,b), prepared mainly under a periglacial climate during the slope's transformation and the denudative lowering of the Prządki elevation.

While the rock complex of greatest hardness was prepared, destructive factors such as congelifraction (frost weathering), insolation, solifluction, suffusion, corrosion, and deflation started to affect all surfaces, leading to the formation of isolated rocks, such as rock pillars (Figure 2a,b) and ridges (Figure 2c). The type of Cieżkowice Sandstone weathering, mainly granular disintegration, was determined mainly by the stone's lithological character. The extensive niches at the bases of many rock formations were caused by the intense activity of the weathering processes mentioned above on the beds of poorly sorted and cemented conglomerate sandstone. The erosion was most intense in areas of diversified substrate resistance, such as along joint cracks. The subsequent stages of the Prządki rocks' morphological transformation are the result of large-scale movements, e.g., rockfalls and landslides, gravitational settling, down-creeping, and bioerosion (Figure 2g)—a result of vegetation appearance [33,74].

Presently, weathering structures can be observed on the surfaces of the rock formations. The rich microrelief of the rock surface (Figure 3) can arouse tourist interest, thus constituting an excellent educational area for the needs of geotourism.

Most visible are [33,74]:

- Cellular structures of a honeycomb type (Figure 3a);
- Weathering ferricrust (Figure 3b) and dark-grey limonite crust (Figure 3c), present in areas of ferrous iron mineral concentration and recrystallization;
- Areas of exfoliation (Figure 3c,d) observable on the flat and almost horizontal rock surfaces and characterized by specific flaking of the surface of the thin sandstone layer;
- Bowl structures (Figure 3e), formed as a result of primary cement dissolution and the decomposition of unstable mineral components, followed by the recrystallization of secondary mineral compounds at the periphery of the eroded surfaces;
- Vertically developed grooves of a pseudokarren type (Figure 3f);
- Arcade structures developed along the bedding surfaces (Figure 3g);
- Single oval holes (Figure 3f) arranged chaotically on the side rocky walls, featuring traces of mud balls or larger pebbles removed by weathering processes;
- Weathering pits (Figure 3h), with diameters from several to several dozen centimeters, usually infilled by water and developed on the top surfaces of the sandstone tors.

#### 4.1.2. Bio- and Geo-Diversity Interactions

The nature reserve features typical vegetation in the sandstone substrate, where acidic soils develop. The trees are mainly fir *Abies alba* with an admixture of beech *Fagus sylvatica*, sycamore *Acer pseudoplatanus*, spruce *Picea abies*, and pine *Pinus sylvestris*, as well as acidophilic shrubs, such as *Vaccinium myrtillus*, *Maianthemum bifolium*, *Frangula alnus*, and *Pteridium aquilinum* [74].

High lichenological values were observed in the research area [89]. The species of lichens occurring here have various colors (Figure 3e,f), which can be easily observed on the surfaces of rocks. The geographic diversity related to the shape and micro-reliefs of the rocks, the degree of inclination, the size and exposure of rock surfaces, also as insolation and shade determine the formation of many diverse microhabitats. Some demanding species of lichens are attached only to strictly defined places, e.g., rock crevices, rock foothills, northern or southern exposures, higher or lower parts of rocks, rock peaks, etc. Similar dependencies in forest phytocoenoses, meadows, and grasslands were observed within the nearby rocks of the Kamieniec Hill [90]. The bedrock is also important for lichen. Although most taxa are associated with a substrate devoid of calcium carbonate, completely different growths occur in the places of greater calcium carbonate accumulation (known as calciphilic species) [89].

The bioerosion mentioned above is the easiest way to observe the mutual relationships between geodiversity and biodiversity. Trees and shrubs are most often found on and in the vicinity of rocks, and the roots of trees growing into the gaps widen the rocks (Figure 4a). The weathering of rocks, both physical and chemical, is also influenced by lichens (Figure 4b). This influence is observable through their thalluses, which contain individual quartz grains separated from the Cieżkowice Sandstone.

The rapidly progressing plant succession led to the loss of the landscape character of the geotourism object. The first scientific studies [75,76], the photographic documentation of the area (Figure 5), the long—dating back to the 18th century—history of tourism [91–95], as well as the high contemporary interest in the site, support the necessity to take care of the landscape values through geoconservation [37,96].

#### 4.1.3. Human and Abiotic Nature Interactions

Picturesque rock formations have long attracted human attention. The name “Spinners” and the related legends appeared in literature at the turn of the 19th and 20th centuries [97]. The names of individual rocks are an example of so-called geom mythology [94,98], i.e., attempts to explain the genesis of sandstone tors undertaken in times before the development of geological sciences (Figure 2a,b). Rocky formations of Czarnorzki were popular in the 18th and 19th centuries, as evidenced by the historical guidebooks and geographical studies. They were also an inspiration for painters, writers, and poets, thus becoming an element of the Polish Romantic tradition [91–95].

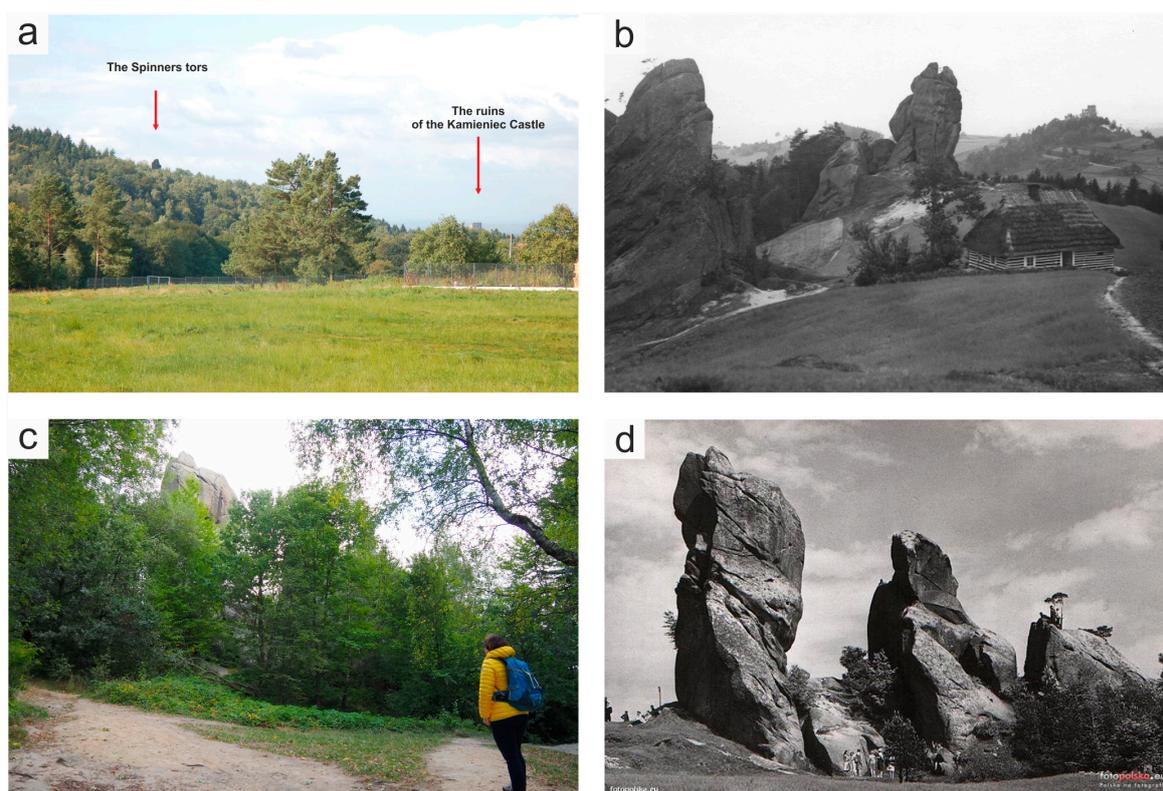
Outcrops of the Cieżkowice Sandstone in the Prządki Nature Reserve were excavated in previous times, and stone exploitation was still active here (Figure 2c) in the first half of the 20th century [40]. Intense activities aimed at protecting all groups of rock formations by nature reserve establishments have stopped this practice already [34–37,39,74–76]. Traces of the former stonemasons’ activity can be found in the central part of the reserve (Figure 6a).

Despite a strict ban, rock climbing is practiced on the sandstone rocks of Prządki, as evidenced by traces of magnesium carbonate (Figure 6b), the most common chalk used by climbers. Magnesium carbonate and other substances that facilitate climbing are difficult to wash away through rainwater and remain on the rocks for a long time, sealing the surface of the sandstone. The natural process of moisture migration from deeper parts of the rock is thus blocked, causing its cementation with secondary minerals. As a consequence, weathering crust development is intensifying, leading to faster destruction of the surface. Attempts to mechanically remove magnesia traces also lead to granular disintegration of the sandstone’s surface stability and flaking [99]. Amateur graffiti (Figure 6c) painted on the exposed and clearly visible walls of the rocks results in a similar type of devastation. In addition, graffiti is indelible, so it disfigures the light sandstone surface for a long time, reducing the landscape value of the overall surroundings [39].

Massive and stable rocks in some areas are strongly cracked, and larger fragments of sandstone may be torn off. A good example can be observed in the upper part of the Prządka–Matka rock formation, where stabilization of a large stone block was undertaken in 1989 (Figure 6d). The gradually widening crack was secured with metal clamps and reinforced by concrete fasteners [39].

The area of the nature reserve is available for tourists, and convenient sightseeing is provided by two car parks located nearby the reserve’s western and eastern ends (Figure 1). The western entrance is marked by information panels (Figure 7a) indicating the most interesting rock formations. The educational tourist path contains small information panels indicating the most famous rocky formations (Figure 7b) as also wooden stairs and handrails in steeper terrain.

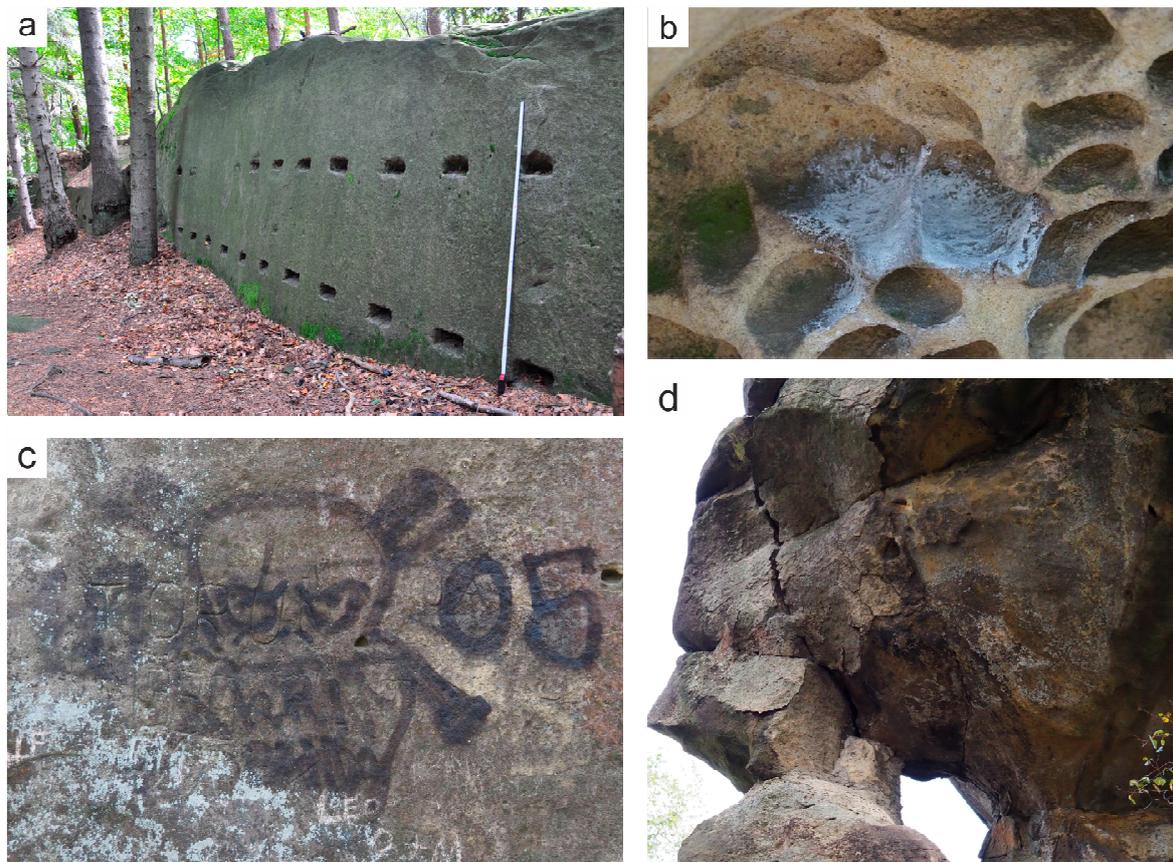
A few geotourism products (of various scientific complexity levels) exist in the reserve area. Two simple geotourism panels are located in the neighborhood of the Prządka–Matka rocky form (Figure 7c). The more scientific panel (Figure 7d), part of the “GeoKarpaty” cross-border project [38], can be found in the area of the eastern car park in Czarnorzeki village and contains information about the genesis and significance of the Prządki rock formations’ geological heritage. Despite the delineation of the walking path, tourists still descend from the trail to the reserve area. This is due to both the lack of a clearly marked prohibition and the presence of wild paths trampled by years of uncontrolled tourist traffic. Security infrastructure (barriers, handrails, and steps) installed along the marked path can channel tourist traffic only in more difficult weather conditions (rain, snow). There are no designated picnic points, shelters, or litter bins in the area of the reserve, which results in littering of the area.



**Figure 5.** Panorama of the Prządki Nature Reserve over the last 100 years: (a) a forest-covered hill with the Prządki tors area, photo by Miśkiewicz; (b) the Herszt tors in the foreground, further the Prządka-Baba group of tors and the ruins of the Kamieniec castle in the background. Photography taken in 1918–1939 by Henryk Poddębski for the purposes of the Illustration Archive of Daily Illustrated Courier (National Digital Archives Database); (c) tors of the Prządka-Baba covered by vegetation, photo Miśkiewicz; (d) tors of the Prządka-Baba recorded in the photo from 1958–1960 made by G. Russ, PTTK (Polish Tourism and Sightseeing Society) postcard. Photographic database “Fotopolska.eu”.

The provision of a reserve area for tourist movement requires better development, including elements of geoeucational communication to legitimize the existing geoheritage protection.

In conclusion, like most Carpathian rocks, the sandstone rocks of the Prządki Nature Reserve have a polygenic origin [33,74,100,101], as follows: (1) the geology of the area—the neighborhood of shales of the Hieroglyphic beds in the south and variegated shales of the Upper Istebna Beds in the north; (2) the variable character of the Cieżkowice Sandstone—variable thickness of beds, the amount and distribution of diagenetic joint plains, chemical characteristics, the amount and distribution of cement, the amount and distribution of sedimentary structures, the size and distribution of mineral grains, etc.; (3) the long-lasting effects of various factors of weathering, erosion, denudation, and mass movements occurring mainly in a periglacial climate, as well as today. Additionally, anthropogenic activities—historical sandstone excavation, present-day acts of vandalism, rock climbing, etc.— have changed some parts of the sandstone tors.



**Figure 6.** Examples of human activity in the area of the Prządki Nature Reserve: (a) traces of stonemason activity—holes after splitting by wedges in the rocky ridge located in the center of the reserve area; (b) traces of magnesia (bouldering climbing) remaining inside the cellular structure on the sandstone of the Prządka–Matka complex; (c) example of graffiti as a manifestation of vandalism in the area of the Prządka–Baba rocky formation; (d) example of a geohazard—a sandstone block with a risk of falling in the upper part of the Prządka–Matka tower. Photos by Welc and Miśkiewicz.



**Figure 7.** Information development in the area of the Prządki Nature Reserve: (a) information panels at the western entrance to the area of the nature reserve; (b) small information panel highlighting the most attractive rock formations; (c) geotourism panels near the Prządka–Baba rock complex; (d) geotourism panel of “Geo-Karpaty” (GeoCarpathians) cross-border geotourism route. Photos by Welc and Miśkiewicz.

#### 4.2. Compilation of Elements of the Geotourism Potential

For the selected geotourism object of the Prządki Nature Reserve, the geotourism potential was compiled according to the proposed method described in Section 3, and a synthetic summary of its geotourism potential is outlined in Table 4. This site was selected because of its uniqueness, representativeness, high geoh heritage values, and thematic diversity [36,37,74,96]. It is characterized by good tourist accessibility but still features in only a few geoe educational studies [39].

The geotourism potential compilation presents a set of features that are most easily recognizable macroscopically within this geotourism object, which are divided as follows:

- Features resulting from the way in which the Ciężkowice Sandstone (Rocks) was formed and the morphology of its rocky forms (Relief), which is based on part A of Dowling’s ABC geotourism [31];
- Features related to the influence of geodiversity on vegetation and vice versa (bio- and geo-diversity interactions), presented as part B of Dowling’s ABC geotourism [31];
- Features reflecting human activity within Prządki and its surroundings, from both an historical and a contemporary perspective (human and abiotic nature interactions), representing part C of Dowling’s ABC geotourism [31].

Recognition of each of these features (the identifiable elements of geotourism potential in Table 4) is considered from perspectives of both a specialist (“scientists” in Table 4) and a visitor (“tourists” in Table 4). The tourist observations are based on organoleptic features that are recognizable by means of the senses (vision—e.g., color, size, and shape; touch—e.g., texture and roughness; taste—e.g., a salty taste; smell—e.g., a sulfuric scent; and hearing—e.g., sound). Everyone can easily identify these features when visiting the geotourism object. The recognition of tourists’ perceptions is based on

interviews with tourists carried out during geological field works. Additionally, the didactic experience with students' field classes has been taken into consideration. In the last column (the examples of geoeeducation issues in Table 4), an exemplary range of geoeeducational topics is proposed—for field teaching, geointerpretation and the development of geoeeducational materials are considered.

Due to the common presence of clastic sedimentary rocks (sandstones and conglomerates) and the good development of their typical features, this can be a representative area for presenting sedimentology issues. In this context, the object can be classified as a paleoenvironmental object. The lithological features of the rocks are easily recognizable (e.g., their grain shape and the associated transport route, the nature of the cement through an HCl reaction, recognizable rounded quartz grains, angular feldspars, and the basal cleavage of micas). Sedimentary structures are also noticeable, e.g., bedding, parallel or diagonal laminations, and amalgamation.

However, the most characteristic features of the Prządki Nature Reserve are the rocky forms and their surface microreliefs, which make the area primarily a geomorphosite. Geoeeducational issues related to the diversity of shapes and textures of the microreliefs (e.g., cellular and arcaded structures) and the results of selective weathering processes (corrosion, suffosion, etc.) can be presented here due to their recognizable relationship with the lithology, sedimentation structures, and tectonics (square cracks in the sandstone).

The Prządki Nature Reserve can also be classified as a geo-ecological object due to the common presence of multicolored lichens occurring on the surfaces of the rocks and the tree roots growing into the rock crevices, which affects weathering. The geodiversity–biodiversity link is not as obvious for non-scientists and, therefore, requires more advanced geointerpretation.

The study area is of importance to the local history, culture, and tradition, which entitles it to be classified as a geo-cultural object. Due to the fanciful shapes of the area's rocks, which resemble human figures, a few legends and tales exist, making the geotourism object more attractive to visitors. A comparison of the mythological origins of the rocks (geomythology) with current knowledge may also help explain the scientific method and the ability to distinguish scientific fact from myth. Moreover, signs of historical exploitation in the form of wedges are observable here.

The vegetation growing around the rocky forms has a negative impact on the geotourism object due to an impoverishment of the area's visual value. This feature may be used when presenting geoconservation issues. Various nature protection methods have been used here, such as establishing a form of protection, providing tourist infrastructure, including information with warnings for tourists, and forbidding climbing. Compiling the geotourism potential of the Prządki Nature Reserve indicates that the presence of tourist infrastructure is an element of protecting nature, as is education in this area.

## 5. Discussion and Concluding Remarks

The proposed definition of geotourism potential and the method of its compilation along with its application on a selected example of a geotourism object yielded the following observations:

1. Geotourism is a type of cognitive tourism; therefore, geotourism potential concerns a range of geoeeducational opportunities. The task of geotourism is, among others, to create new tourist attractions and generate tourist traffic [4,12], but the subject of interest—geodiversity and geoheritage [12–19]—is strictly defined, as is the goal—geoeeducation [4,22–24]. This is emphasized by Dowling [31], who notes that for the development of geotourism, “*understanding the identity or character of a region or territory*” is important. Therefore, what distinguishes geotourism from other types of tourism is the orientation of the tourism activity towards exploring and understanding the heritage of the Earth, particularly its importance for the biosphere and humans. The division of geotourism potential is also inspired by the ABC geotourism model [31], which includes abiotic features (geology and geomorphology), as well as biotic and cultural features related to the geological foundation (Table 4).
2. Geotourism potential should be compiled for the clearly developed genetic features of geotourism objects. The selection of such objects should be made based on only one criterion—the readability

of the geological and geomorphological features [49,52,53]. Researchers should pay attention to the features of an object that attract tourists' interest and are legible and easily recognizable [52,53]. These factors determine the potential (see definition in Table 1) of a geotourism object to be used in geoeducation.

3. The method for geotourism potential compilation is not the same as an inventory or assessment of a geotourism object. These methods allow one to select geotourism object that, after tourist development and the provision of proper educational materials, have a real chance to become new tourism attractions [8,12,102]. In the inventory process, the observed features of the object are compared and described in detail [58]. During assessment, these features are assessed either against features of other objects or against a developed pattern and given criteria (e.g., [71,103]). These criteria may include geodiversity, geoheritage, or geomorphological heritage assessments [19,39], listings for geoconservation and geotourism [59], object attractiveness rankings for different types of recipients [12,22], and evaluations of a narrow range of geosite values [46,49]. Compilation of the geotourism potential involves supplementing the information contained in the inventory sheet with geoeducational factors. For a strictly determined group of geotourism object features (readability), issues that may be geointerpreted and used in the education process should be considered.
4. The compilation of geotourism potential is related to specific types of geotourism research, including (1) inventory and documentation, (2) the compilation of geotourism potential, (3) the assessment of geotourism attractiveness, (4) designing geoeducational materials, and (5) the creation of tourist infrastructure. In the process of gathering knowledge about a geotourism object, geotourism potential is best compiled after the inventory and documentation of the object and before geotourism assessment. However, if necessary, this process can be supplemented at a different stage of creating or reorganizing a geotourism attraction. Geotourism potential may be helpful for assessment, especially for estimating the cognitive value of an object for various types of recipients [12,102].
5. Geotourism potential is not subject to assessment. Current assessment models [19,39,59,103] assess, inter alia, the cognitive (didactic, pedagogical, educational, and interpretative) values of geosites, indicating objects of greater or lesser scientific importance. However, for geoeducation aimed at a non-professional recipient (a tourist), the scientific weight of individual characteristics does not matter. It is more important that this recipient be able to recognize and remember these features on his or her own. The definition of geotourism potential proposed in this article defines a single, qualitative criterion for assessing each of the features that comprise the geotourism potential of an object—legibility. Particular geotourism objects will differ in the amount and scope of their features with geotourism potential, but the only task of these values is to define the directions of geoeducation, not its value.
6. A location convenient enough to make the geotourism object available is a debatable criterion and should not be considered in geotourism potential compilation. The accessibility of even a very unfavorably located site to the general public depends only on the amount of financial resources invested in appropriate tourist infrastructure, e.g., the Chinese Huashan Mountains [104] or the Zhangjiajie Glass Bridge [105].
7. Tourism infrastructure is not a component of geotourism potential. It is unnecessary to analyze the elements of tourism and information development as components of geotourism potential. While the substantive scope of geoeducation depends solely on the amount of clear cognitive values represented by the site, the quality and quantity of tourism development (including trails, picnic areas, stairs, railings, sanitary facilities, accommodation, food, etc.) have nothing to do with cognitive values and consist of variable elements, dependent on many factors (including land ownership, the amount of financial resources allocated for investments, municipal development strategies, and tourist traffic). The information infrastructure in the vicinity of the geotourism object should be treated similarly (e.g., information boards and geotourism panels). The quality

or quantity of such information may be improved at any time. The perception of a tourist object from the perspective of its tourist potential, along with its development (technical and information facilities for tourists), determines the tourist attractiveness of an object, not its geotourism potential.

8. The type of tourist, the level of his or her knowledge, and the scope of his or her interests have no influence on the compilation of geotourism potential. The thematic scope of geotourism potential is determined only by the readability of geotourism object features. Selection of the substantive level and scope of knowledge presented to the tourist and selection of the techniques and tools for the presentation of this knowledge are accomplished only at the stage of gointerpretation followed by geoeducation.
9. The concept of geotourism potential should not be equated with the concept of educational potential. Education, understood as *“all processes and interactions aimed at changing people ( . . . ) according to the ideals and educational goals prevailing in a given society”* [106], needs didactic methods and tools, so a geotourism object can only fulfill an educational function when it includes appropriate tourism and information development along with appropriate gointerpretation. The properly determined geotourism potential of a geotourism object provides only the foundation for designing geoeducational materials.
10. The geotourism potential of a geotourism site should be analyzed more broadly than the object location itself. Due to the artificial delimitation of boundaries (e.g., a nature reserve) and the frequent presence of important elements of geoheritage at a certain distance from the analyzed geotourism object, when compiling geotourism potential, the object’s surroundings should be considered. For example, the use of the Cieżkowice Sandstone forming the picturesque rocks of the Prządki Nature Reserve can be seen in historical buildings of the nearby Kamieniec Castle (Table 4), located approximately 1 km west of the study area [39].
11. The compilation of geotourism potential is an expert method. Due to the necessity of specialist data compilation in the fields of geology and geomorphology, as well as the bio-geodiversity interactions and human-abiotic interactions in nature, this method can be used only by specialists in the field of Earth sciences. Supplementary issues may need a specialistic consultation with other scientists (like archeologists, historians, biologists, human geographers). The obtained results are intended for use in geoeducation, which is one of the activities in geotourism. The indicated sequence of the individual stages of geotourism potential compilation emerges from practical use of the authors’ knowledge and experience working with geotourism issues—in particular, developing the substantive scope of geotourism panel designs. The model is based on the literature and field research, followed by a proper division of the results and their strictly defined presentation in the form of a table. This model is qualitative, not quantitative. Since there is no judgment, there is also no subjectivity.
12. The compilation of geotourism potential is a universal method. It was presented on a representative group of rock formations in the Carpathians (Prządki Nature Reserve), but the versatility of this method means that it can be successfully used for each identified geotourism object, as well as for an existing geotourism attraction. This method uses a simple procedure (4 stages), provides a clear diagram (4 thematic categories), and has synthetic characteristics (the form of a table). For the present geotourism object, the Prządki Nature Reserve, all thematic categories of potential are represented and legible (rock, relief, geo-bio interactions, and human–abiotic nature interactions), which confirms the unique value of the object on a global scale [37]. Geotourism potential can be compiled not only for natural objects but also for *“all aspects of human activity that use the Earth’s resources or refer to them directly”* [22]. For example, this potential could be determined for an architectural object whose construction used local rocky materials, a geological museum exhibition, events such as gold panning, mineral exchanges, etc.
13. The result of geotourism potential compilation has high practical value. Geotourism potential involves a set of geoeducational issues developed based on the visible features of an object

and can be used by experts when designing geoeducational materials and tools. It may also serve local administrators, geotourism site owners, or activists, thereby facilitating decisions on financing the development, sharing, and promotion of geotourism objects and thus creating geotourism attractions.

14. The features noticed by tourists are a key element of geotourism potential, whose compilation (Table 4) includes a column specifying the features of the objects identified by the tourists, such as shapes, colors, textures, etc. Since these factors usually attract a tourist's attention in the first place, and thus arouse interest in their origins, they can be considered as the basic features (features of the first order) for the geoeducation process. These features are easy to identify and describe because they are clearly visible. Notably, what tourists focus on may differ from the typical geological and geomorphological features considered by a specialist to be important in geoeducation. For example, in an area similar to the Prządki Nature Reserve, the Skamieniałe Miasto "Petrified Town" Nature Reserve in Cieżkowice (Carpathians), tourists most often notice the tilt of the rocks and an impression of "their imminent overturning" (based on an oral message from the guide). Such a feature will be considered by a specialist in the context of the gravitational mass movement of rock formations but will likely not be considered of great importance in geoeducation. It is possible to consider such observations important in the geoeducational process, but this process would require additional survey research among tourists to the geotourism object. The second group of geotourism potential elements are those that are noticed by a specialist analyzing the site but are usually invisible to the tourist (due to a lack of professional knowledge). In the process of geoeducation, these elements can be considered secondary features (features of the second order). Finally, the third group consists of invisible features [107]. For example, in the Carpathians, the micropaleontological geoheritage resulting from the presence of foraminifera facilitates, for example, the dating of rocks. Such features can be considered tertiary to the process of geoeducation because they require advanced geointerpretation (features of the third order). Their use in geoeducation is often not direct. Information about the presence and origin of such features is provided as a more specialized complement or extension to a geoeducational topic based on easily noticeable features. In this article, we emphasized the importance of first order features for geoeducation, but the model for the geotourism potential compilation (Table 4) was based on a comprehensive list of first and second order features. Features of the third order are present in the compilation in the form of geoeducational topics that can be used depending on the nature and level of the recipient's knowledge.

Consciously practiced geotourism, aimed at learning and understanding the processes shaping the Earth, is used to achieve the goals of geoeducation, which is a part of non-formal education [108]. Geoeducation can be implemented in two ways. For example, tourists may be asked about their interest in the object, and their answers may provide the basis for the creation of appropriate materials and educational tools. Conversely, previously prepared tools and materials may be proposed, thereby directing tourists' attention to the clear features of the geotourism objects and thereby explaining the geological processes and genesis of the object. The method of geotourism potential compilation successfully replaces the methods described above. It allows one to immediately focus on the elements of the object that are attractive to tourists and thus determine the scope of possible geoeducation.

Contemporary geotourism is a tourism movement focused on objects representing the heritage of the Earth, as well as scientific activities involving the documentation, assessment, and geointerpretation of this heritage (with a focus on tourist accessibility) and the management of the area, which determines geotourism activity. There are three main types of users of geotourist content [12]: tourists (including enthusiasts and guides), scientists, and investors (owners and managers) of geotourist facilities or areas. The properly defined and compiled geotourism potential of an object provides the basis for the activities of each of these groups. For tourists, a list of features provides the primary sources of interest; for scientists, a list of the most important elements for geointerpretation and the development of geoeducational content

is the main focus; and for investors, this method highlights the direction of necessary investments to make.

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