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A New Geosite as a Contribution to the Sustainable Development of Urban Geotourism in a Tourist Peripheral Region—Central Poland

Maria Górska-Zabielska

Institute of Geography and Environmental Sciences, Jan Kochanowski University, 25-406 Kielce, Poland; maria.gorska-zabielska@ujk.edu.pl

Abstract: The article presents a new geosite in a small provincial town in central Poland. It contains twelve Scandinavian erratic boulders from the area, deposited by the Pleistocene ice sheet about 130,000 years ago. The geotrail is equipped with three informative boards, a folder, and each boulder has its own identifier. The article also draws attention to petrographic types and types of erratic boulders among the collected boulders. Their basic dimensions, age, and source area are given. Specific features of rock morphology are discussed. Records of sub/inglacial processes, periglacial processes affecting the forefield of the melting ice sheet, and contemporary morphogenetic processes are also analyzed. The recipient/beneficiary of such information can be anyone who is sensitive to the beauty of abiotic nature, feels heir to the geological past of his region, or wants to broaden his horizons with knowledge from the ice age. The recognized and disseminated heritage of abiotic objects in nature through the transfer of expert knowledge has great potential to become an effective generator of sustainable socio-economic development of peripheral tourist areas. The paper presents in detail expert knowledge and specific examples of improving the quality of life with the creation of this geosite. The tool to be used here is geotourism; it deals with the study of geodiversity and the development of elements of abiotic nature to perform tourist functions in accordance with the principles of nature protection. It protects the geological heritage by effectively securing geosites, widely disseminating geological sciences, and promoting their educational and tourist functions.

Keywords: geosite; geotrail; Scandinavian erratic boulders; urban geotourism; sustainable development; Central Poland

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1. Introduction

One of the basic and necessary needs for normal human functioning is rest and recreation. He/she satisfies this need in different ways, depending on many factors. He/she often exhibits tourist behavior away from his small homeland, especially when the immediate vicinity does not provide him/her with attractive facilities or when it represents an area that is indifferent or peripheral in terms of tourism [1]. In the absence of known natural and cultural heritage sites, there is no magnet to attract a potential tourist. The lack of widely known tourist facilities/products does not mean that the region has nothing else to fill this gap. Geotourism, a new branch in the tourism sector, shows that even objects that are little known to a wider audience, if only well interpreted [2–4], can satisfy the recipient's cognitive need. Geotourism is based on two pillars: 1. Inventory and development of geological objects of the Earth 2. Education/dissemination of the Earth's geological heritage. It can be implemented both away from large cities (e.g., [5–7]) and in urbanized areas (e.g., [8–15]), where geotourist attractions in unattractive places can be brought out.

The basic object that focuses the interest in geotourism is a geosite and/or a geomorphosite. It is a natural site [2,16–20] of geological/geomorpholigical interest, where the connection between the processes shaping Earth and the resulting forms, functioning in the past and still affecting the present, is evident. Geosites represent those assets of geoheritage that should be examined, protected, and developed in order to guarantee that future generations have the possibility of exploring Earth's geological past, enjoying sites' natural beauty, and enhancing socio-economic development. It may be an erratic boulder which is an element of stony material eroded, transported, and deposited by the Scandinavian ice sheet at some distance from a source region.

Erratic boulders serve a variety of functions and roles [13,14,21–33]. They belong to the geological heritage of the region and contribute to its geodiversity. They are evidence of geological processes that took place at the time of formation of the ground structure (source area) and glacial transport, and archive the geomorphological processes that affect them today. These values are part of the scientific significance of the object. Another important meaning of the boulder is an educational one, especially in the vicinity of the school. The geography teacher will show details of the petrographic type of the rock (granite, deep igneous rock) and will talk about the geological processes that were responsible for its formation. The surface morphology of the rock block says a lot about the stage of glacial transport of such an object from its place of origin in Scandinavia to the place of deposition. However, it also bears traces of modern morphogenetic processes. It happens that the boulder is colonized with lichens (epilithic flora). This means that an object of abiotic nature is an ecological niche for objects of animate nature. It is not uncommon for erratic boulders to form the basis for memorial plaques; boulders perform a cultural function in such situations. Erratic boulders of appropriate size in the area of glacial deposition (=Peribalticum) are protected as monuments of abiotic nature—then they play a geoconservation role. Erratic boulders placed in representative places of the city/village, e.g., on a square (or in front of a school), successfully play an aesthetic role. Not without significance is the knowledge of the inhabitants of the region about the geological past of their region. Properly exposed objects of abiotic nature maintain and strengthen the geographical character of a place—its environment, culture, aesthetics, heritage, and well-being of its inhabitants. Their role in the sustainable development of the city/municipality/district cannot be overestimated e.g., [34–36].

All of the above-listed reasons justify the protection of this unique geoheritage [37]. They are described in detail in chapter 5 of this article.

Large erratic boulders recorded in Poland are subject to geoconservation and are protected by law [38] as monuments of abiotic nature. Therefore, the largest (860 m^3) boulder in Poland, Trygław in Tychów in Central Pomerania (northern Poland), is of conservational importance. The largest erratic boulder in Pruszków (vol. 4.6 m^3), standing next to the Museum of Ancient Mazovian Metallurgy (https://mshm.pl/en/ [accessed on 10 February 2023]; Figure 1), is also of such importance.

The Polish Nature Conservation Act of 2004 [38] is devoid of a provision clearly addressing criteria (e.g., dimension, petrographic type, cultural heritage object) upon which erratic boulders should be protected. In Germany [39], igneous erratic boulders with a minimum volume of 10 m^3 (the longest axis α = 3.5 m) within the Weichselian Pomeranian Phase [40–42] are protected. It has a minimum volume of 5 m^3 (the longest axis α = 2.5 m) in the area between the Pomeranian and Poznań/Frankfurt phases and about 1 m^3 (the longest axis α = 1.5 m) in volume in the area located south of the Poznań/Frankfurt Phase. All sedimentary erratic boulders, regardless of their size, are also protected (due to the lower resistance that such rocks have to physical and chemical weathering).

The lack of such a provision in Polish law results in increasingly frequent acts of vandalism (such as spray-painted graffiti and the boulder being broken into fragments for windowsills, floors, gravestones, etc.) and theft. Not everyone understands the necessity of the geoprotection of erratic boulders, hence they disappear from the environment [43].

Figure 1. The largest erratic boulder—granite Småland—in Pruszków, the only current monument of abiotic nature protected by law in the Pruszków county. The exposed erratic boulder performs geoconservation, pro-environmental, and educational functions. Photographs were taken by the author, unless stated otherwise.

The interesting structure and texture (size and shape) of the boulder crystals, and often their colour, are the reasons why they have disappeared (Figure 2) and are still disappearing from the landscape. Most often, they are appropriated to private collections. They are also an ideal material for stonework [44,45] for an individual client (e.g., tombstones, windowsills, e.g., at Prusa 48 Street; see Figure 8a,b in [46], kitchen countertops, stone floors) and for large investments (building cladding [43,47], interior design of large companies, road repair, or new stone paving [48,49]).

Figure 2. Sandstone with an eolian corrasion ridge developed in the conditions of the periglacial climate. In March 2019, it was located near the intersection of two city streets. Today there is no trace of it.

Hence, the initiative to protect erratic boulders should be recommended and popularised by locating the objects in one place and equipping them with boards and modern media employing smartphones and tablets, informing the public about the importance and role of geoheritage in the modern world's functioning (e.g., [8–15]). Geointerpretation through storytelling [2,3,50] should not be omitted. Rock collections most often take the form of rock gardens or abiotic trails.

The geosite presented below (52°10′35.6′′ N 20°48′22.2′′ E) was created as part of the city of Pruszków's 2022 civic budget, which involves a process of social consultations aimed at including residents in deciding on part of the city's civic financial resources. Today, civil society is increasingly becoming a determinant of the new spatial order. It has an impact on shaping the space around it through social participation. The author of this paper, a resident of Pruszków, was the project initiator who submitted the project to the participatory budget on the terms and in the manner specified in local municipal law [51,52].

2. Objectives

The aim of the article is to present a small (L-shaped strip 30 m long and 3 m wide; Figure 3) geopath consisting of 12 erratic boulders, a narrow element of a huge geoheritage that can meet the recreational and cognitive needs of residents and tourists. The author will show that the geosite can also serve the local community in many other ways.

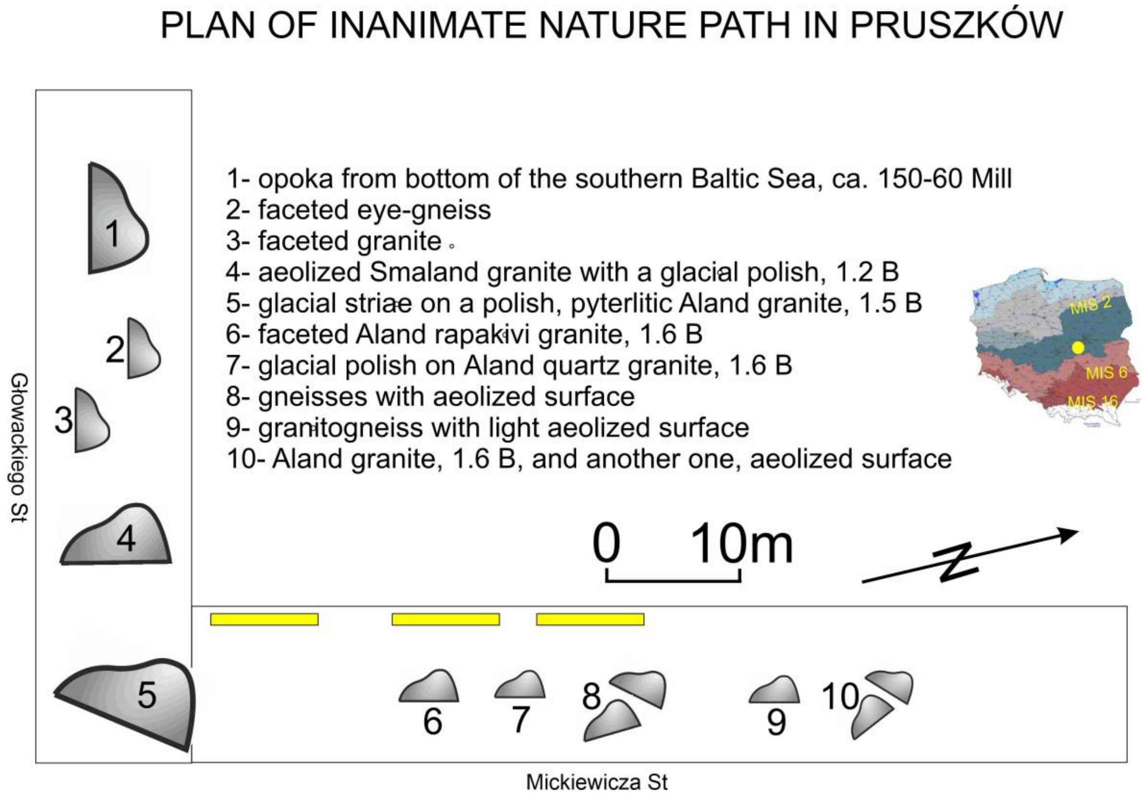

Figure 3. Plan of the geotrail in Pruszków. The location of the city (yellow dot) and main glaciation ranges (MIS16—Cromerian, MIS6—Saalian, MIS2—Weichselian, Last Glacial Maximum) are given on a small map. Source: https://zywaplaneta.pl (accessed on 26 May 2023), changed.

The value of geodiversity [53], that is diversity or variety of geological structures and processes, including rocks and minerals, fossils, geomorphology, sediments and soils, and hydrology) often goes unnoticed, and this article contributes to the dissemination of the importance of geological aspects and gives a sense of identity to local residents. The author's intention, through this work, is also to develop a sense of responsibility for environmental protection in general, and in particular, for aspects of the earth sciences, which are often not given due attention.

The functioning and resonance of the geosite among the inhabitants is the author's hope for the sustainable development of peripheral tourist areas, which are most often the suburbs of large capitals cities. The fact that Pruszków is not attractive to tourists in the usual sense does not mean that urban geotourism cannot develop there. Numerous geosites have already been identified in the city (e.g., [47]), based on which this type of tourism already functions here. In light of this research [51], residents aspire to live in a smart city, which is characterised by innovative solutions and opportunities. After all, wise management of natural resources through civic participation or expert support can generate a positive impulse for innovation, the overriding goal of which is sustainable economic development and a high quality of life. This work is an excellent example that the lack of compatibility existing in Mazovia [52] between universities and the dynamically changing market of ecosystem services and the needs of residents can effectively be addressed in Pruszków.

3. Study Area

The provincial town of Pruszków (63,000 inhabitants in 2021) is located in central Poland, 20 km southwest of Warsaw, the country's capital (Figure 3). It is located within the range of the Wartanian glaciation, the Central Polish complex, Late Saalian (MIS 6) [54,55]. The flat relief in the area is sometimes diversified by the presence of erratic boulders [46,47].

4. Applied Methods

Carefully selected, after a detailed inventory, erratic boulders located within the city limits were transported on 30 June 2022 from their previous locations (Figures 4 and 5) to the geotrail. This is a path along which abiotic objects are arranged, united by a common theme or motif. Such georoutes connect geoobjects of unique geological interest and are suitable for education, research, and tourism activities [56]. According to [57] "the geological routes connect geosites in a sequential and orderly manner to represent a given sector's geodiversity. These tours are self-guided and designed to know the natural space's characteristics through a route where stops are established. Materials such as information panels, explanatory brochures, and a guide allow the correct interpretation of the places". A local company took care of organising the transport and placing the boulders in the new location. Hiring employees from the immediate vicinity supports the sustainable economic development of this region.

Figure 4. Loading of erratic boulder no. 1 in front of the seat of the Social Insurance Institution.

Erratic boulders were donated free of charge by private donors or were moved from the lane of the road hosted by the city of Pruszków or Pruszków county (Table 1). In two cases (boulders no. 1 and 5), the previous administrator agreed to move the boulders to their current location.

Figure 5. Loading of erratic boulder no. 9 from a private property.

Table 1. Information on erratic boulders within the geotrail in Pruszków.

	Rock Type, Origin, Age	Special Features	Diameter [m]	Volume [m^3]	Weight [t]
1.	Opoka, bottom of the southern Baltic Sea, ca. 150–60 Mill	Sedimentary rock	5.6	1.59	4.36
2.	Eye-gneiss from the Baltic Shield, 1.2–1.5 B	Eolised surface relief, faceted rock	2.5	0.16	0.43
3.	Granite from the Baltic Shield, 1.2 B	Eolised surface relief, faceted rock	2.55	0.16	0.44
4.	Småland Granite, SE Sweden, 1.2 B	Indicator erratic, glacial polish, eolisation on the surface, lichen colonization	5.5	1.04	2.85
5.	Pyterlitic granite, Åland Islands, 1.5 B	Indicator erratic, glacial striae on a polish	5.4	2.40	6.60
6.	Åland rapakivi granite, Åland Islands, 1.6 B	Indicator erratic, faceted rock	2.15	0.07	0.19
7.	Quartz granite, Åland Islands, 1.6 B	Indicator erratic, glacial polish	2.8	0.16	0.44
8.	Gneisses from the Baltic Shield 1.2–1.5 B	Eolised surface relief, faceted rock	3.2 & 2.9	0.11 & 0.1	0.31 & 0.26
9.	Granito-gneiss from the Baltic Shield, 1.2–1.5 B	Light eolised surface relief	2.45	0.08	0.22
10.	Åland granite 1.6 B and another one from the Baltic Shield	Glacial polish, lichen colonisation	1.7 & 1.5	0.05 & 0.09	0.15 & 0.09

Inventory: Maria Górska-Zabielska.

The choice of 12 boulders was mainly guided by their large dimensions, which are conducive to educational needs. They were finally gathered in an empty square, which was intended by the author of the project and the city authorities to become the so-called pocket garden [58]. For each of the 12 boulders, information was collected on the dimensions, petrographic type, and type of erratic as well as special features. The estimated volume of boulders was calculated on the basis of [59] the formula: 0.523 × length × width × height, and weight—assuming that 1 m^3 = 2.75 t.

Attention was paid to the various microforms recorded on the surface of the glacial erratic in the form of e.g., crescentic furrows or glacial polish, the formation of which is characteristic of the subglacial environment, when the boulder transported in the foot of the ice sheet rubbed against a substrate that was harder than the boulder itself. The condition of the corners, i.e., their processing, was also examined, which is evidence of transport in high-energy sub- and in-glacial tunnels. The characteristic micromorphological features recorded on the surface of the boulder in the periglacial environment (e.g., traces of corrosion, eologliptoliths, squares) were also documented. Morphogenetic processes currently affecting the surface of the boulder (e.g., exfoliation, corrosion, colonization with epilithic flora e.g., [60,61]) were also the subject of field analysis.

5. The Significance of Collecting Erratic Boulders

In order to minimise losses among erratic boulders caused by vandals and thieves who are far from the idea of geodiversity, which proves the richness of the geological, geomorphological, and geographical heritages, collections are created in the form of geo-trails/geopaths or petrographic/stone gardens, otherwise known as a lapidary (Latin lapidarius—stone). Therefore, collections of erratic boulders are created mainly to preserve and protect these silent witnesses of the Quaternary glaciations, while providing the opportunity to meet the needs of man in terms of learning about the geoheritage of the region and the necessary recreation and aesthetic experiences. Boulders accumulated in one fixed place occur ex situ. There are examples of the use of these objects (and other rocks, not necessarily erratic boulders) in the literature for educational, sightseeing, or nature tourism (e.g., [14,21–33].

Rock gardens, through their exhibits, perform multiple functions. The rock specimens collected in the lapidary belong to the geoheritage of the region, contributing to its geodiversity. They are a geological showcase of the area.

In the following review of the meaning and functions of erratic boulders, the author refers to examples that form the resources of the geological heritage of the urban area of the city of Pruszków in south-western Mazovia. Similar resources are known from the literature (e.g., [9–11,13,14,47,62].

The main value of an erratic boulder is its scientific value because it provides information about the source area, the directions of ice sheet movement, and the time of deposition of an erratic material. The boulder represents one of three petrographic types, each differing in mineral composition and internal structure (texture and structure), on the basis of which geological processes (e.g., magma crystallization conditions, rock metamorphism/transformation processes, accumulation, lithification, sediment compaction) can be determined, contributing to the rock's formation.

Its Scandinavian origin testifies to the geological processes (extraction and detraction) functioning in the Pleistocene in Northern Europe. If an erratic originates from a specific source area (outcrop) in Scandinavia, it is the indicator erratic (Figure 6) [63–67]. Most of the rest are called statistical ones [68]. The structural and textural features of the rock are used to assign the parent/source area. A statistically representative number of indicator erratics in the layer of glacial deposits can indicate the route of the far migration of an ice sheet to the European Plain (e.g., [55,69–71]).

An erratic boulder is of great scientific value if a record of the detersion process, i.e., grinding and smoothing (e.g., scratches, glacial polishes (Figure 7), crescentic furrows (Figure 8), and micro-depressions) can be seen on the boulder's surface. All of these subglacial processes took place in the sole of an ice sheet at a time when a boulder was still in the source bedrock upon which the Scandinavian ice sheet was moving. This record could also have appeared on the rock's surface while it was already being subglacially transported. The rock anchored in the foot of the ice sheet then rubs against the ground on which the ice sheet moves. Such microforms can be identified on several erratic boulders found in the city, e.g., in front of the Complex of General and Sports Schools in Pruszków, next to the church in the city centre (Figure 8), and on one of the boulders of the newly created geotrail in northern Pruszków.

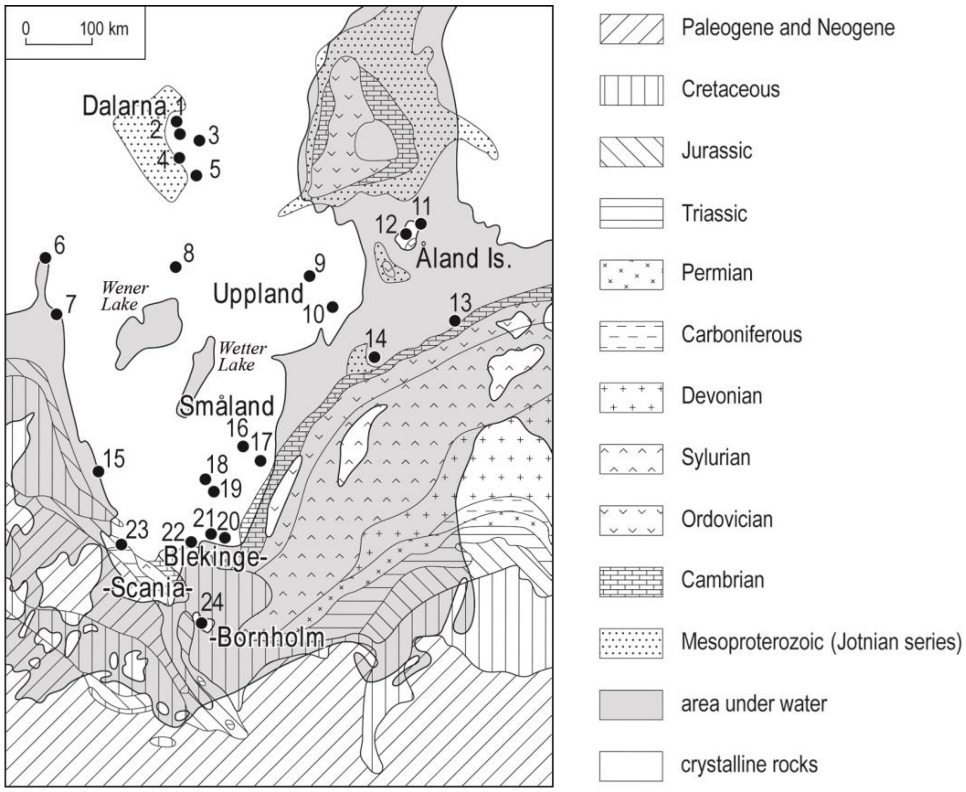

Figure 6. Schematic map of the Scandinavian source areas of selected indicator (dots with numbers, mainly on land) and other (outcrops mainly at the bottom of the Baltic Sea) erratic boulders found in the area of glacial deposition. Explanation of numbers: 1—Bredvad porphyry, 2—Garberg granite, 3—Grönklitt porphyry, 4—Dalarna porphyry, 5—Siljan granite, 6—Oslo porphyry, 7—Bohus granite, 8—Filipstad granite, 9—Uppsala granite, 10—Stockholm granite, 11—Åland granite and Åland rapakivi granite, 12—Åland quartz porphyry, 13—red Baltic porphyry, 14—brown Baltic porphyry, 15—charnockite, 16—Småland granite, 17—Påskallavik porphyry, 18—grey Växjö granite, 19—red Växjö granite, 20—Karlshamn granite, 21—Halen granite, 22—Vånga granite, 23—Scania basalt, 24—granites and gneisses of Bornholm. Source: from author [63] after [39], changed.

Figure 7. Småland granite with a commemorative inscription on an exposed glacial polish on the front and a classic eolian corrasive microrelief on the back side. The upper part of the boulder suffers from exfoliation. The boulder performs a culture-forming function.

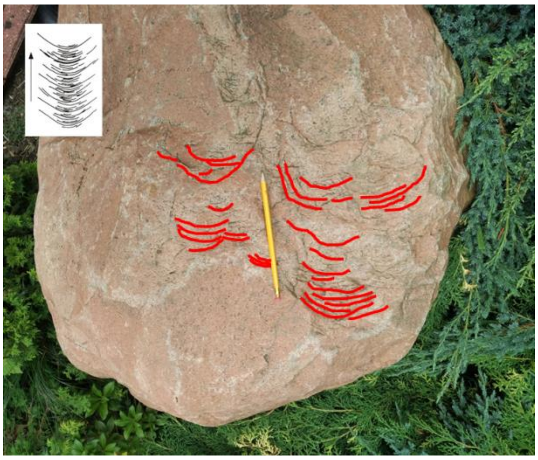

Figure 8. Crescentic microforms on the granite next to the church in the city centre are a trace of subglacial processes in the foot of the ice sheet that functioned during the movement of the ice mass over hard ground.

The post-depositional stage, which begins when the rock load is abandoned by the melting/shrinking ice sheet, may also be recorded on the surface of a glacial erratic boulder. Many morphological features indicate the climatic conditions of the periglacial environment (in the foreground of the "receding" ice sheet) that functioned in the area of glacial depositions. Most often, traces of eolian corrasion are observed in a dry and frosty periglacial environment, e.g., eolisation of the boulder surface, corrasive "smallpox", corrasive microribs, or its clear edge. The morphological effects of such processes are recorded on several erratic boulders in Pruszków (e.g., on a less-exposed boulder hidden in the bushes, Figure 9). The best, so far in Pruszków, record of destructive corrasion processes can be seen by a visitor on two neighbouring Småland granite pieces in the southern part of the city (Figure 10).

Figure 9. A model example of a ventifact with a distinct corrasive ridge, developed on gneiss, may play an educational role in the town.

Frequently, the process of exfoliation (flaking) of a rock block can be observed on the surface of erratic boulders. The main factors of this process are temperature changes and the circulation of water and solutions in the micro-spaces between the minerals. They lead to the rock's disintegration. This process is developing in the top parts of the Småland granite in front of the Museum of Ancient Mazovian Metallurgy (Figure 1) and also in the other Småland granite (Figure 7).

Figure 10. On the surface of both fragments of the Småland granite, there is a classic eolian corrasive microrelief in the form of microribs and microfurrows that were created as a result of grinding the rock surface with quartz grains carried in wind streams in the foreground of the melting ice sheet. The aesthetic and sentimental functions of the boulders are emphasised.

It is not uncommon to associate sets of characteristic indicator erratics with specific ice sheet advances. In this case, erratics are used for stratigraphic recognition of sediments (e.g., [72–76]). In light of many different scientific studies, it is known that all erratic boulders found in surface sediments (or at shallow depths) in Pruszków and the surrounding area were transported during the Wartanian glaciation of the Central Polish complex, i.e., around 130,000 years ago (=younger part of the Middle Polish Glaciation, Late Saalian, Marine Oxygen-Isotope Stage (MIS) 6) [54,55,71,77]. At that time, the area that is now today's Pruszków slowly emerged from under the melting ice, revealing large rock blocks left here and there and the ballast of the ice sheet that was ploughed from the Scandinavia bedrock much earlier.

The most important scientific value of the erratic boulder is its final natural location, unchanged anthropogenically since the glacial deposition. Such a boulder occurs in situ. By indicating the extent of the glaciation, erratics help indirectly to reconstruct changes in the Earth's climate. In addition, such boulders are used in the latest analyses of dating the beginning of deglaciation of glaciated areas using cosmogenic isotopes, e.g., ^{10}Be [78–82]. Sometimes, to identify the time of deglaciation of an area, lichens colonizing on erratic boulders are used (e.g., [83,84]). Today, only very large boulders remain in situ. Thanks to the fact that they have not changed their locations, they constitute an invaluable natural heritage and determine the region's high geodiversity. For obvious reasons, these boulders do not occur in petrographic gardens.

The rock specimens collected in the lapidary document numerous geological processes that took place in the past in the remote region from which the exposed objects originate. The rocks, being the area's geological showcase, are of scientific importance. It is the greater, the richer the record of geological and geomorphological processes in/on the erratic boulder.

The presence of rocks of different origins, sizes, or colours in one place—in the immediate vicinity of the school (e.g., in front of Primary School No. 6 in Pruszków; Figure 11)—means that the lapidarium has great potential as an educational function to be fulfilled. This depends on the involvement of local teachers, not only in geography [85] or science, but also in mathematics, languages, and arts. The core curriculum obliges a teacher to conduct classes in the field [86]. It is worth ensuring that schoolchildren take part in annual events popularising earth sciences, such as Earth Day (21 April), Geodiversity Day (6 November), and International Geomorphology Week (1st week of March) as celebrated in Poland. These events can be organised in the lapidarium area provided that access to the collection is easy, that it is equipped with boards with accessible information, and that it is characterised by proper quasi-touristic developments expected by the recipients (e.g., identification labels on rock specimens, baskets for garbage, places to rest). It is important to have a geo-interpreter who will sensitise students, as well as the non-specialized general public, to the beauty of abiotic nature in an interesting and skilful way (e.g., [2,3,50,85–92]).

Figure 11. The mini lapidarium in front of Primary School No. 6 in Pruszków has educational and aesthetic functions.

Rock gardens/collections can help the local community achieve real economic benefits by first building them and then by developing (geo)tourism accordingly, e.g., [13,14,22–33]. Thus, the following specialists work to expose rock objects: designers and landscape architects, crane and loader operators, employees maintaining greenery, designers and producers of information boards and identifiers, and conservators of the developed space, who make efforts to ensure that the objects remain unchanged and safe for geo-tourists. Then the lapidarium is used by geo-interpreters who, based on its objects, disseminate knowledge in the field of earth sciences.

Effective dissemination of geological heritage by local guides or nature interpreters, as part of festivals or in the form of workshops, ecomuseums, the increasingly popular geocaching/quests, or even fledgling TRInO (http://trino.pttk.pl/ [accessed on 8 February 2023]), and making them available, after appropriate protection, for sightseeing, e.g., as part of a geotourism/educational path, will certainly bring financial benefits directly to the inhabitants and indirectly to the local governments of the regions where these facilities are located (e.g., [2,3,7,8,12]. Self-government authorities aware of their presence in the environment can use the natural values of the area without conflict with their local policy of sustainable social and economic development.

Organising lessons/workshops (Figures 12 and 13) or incorporating the space of a collection of rock objects into the local government's festival programme is also an implementation of the lapidary's recreational function. There is no need to convince anyone of the need for recreation/fun (e.g., searching for minerals/rocks in a sandbox with treasures) and outdoor activities for children.

Figure 12. Educational workshops on the nature trail for geography teachers from the Pruszków county; Photo R. Szewczyk 2022.

Figure 13. Geography lesson on the geotrail for students of a Pruszków grammar school; Photo M. Nowak 2022.

The interestingly designed lapidarium is characterized by harmony and beauty [90–92]. They often enhance the aesthetic value of a long-disused quarry, square, or empty/dead part of the city. A good location for 1–2 erratic boulders may be pocket parks, which strategically break up the density of residential development, reducing congestion and improving the aesthetics of the area [58]. By including greenery and abiotic features (natural elements are a common feature of pocket parks), they promote environmental sustainability, biodiversity, and a relationship with the natural landscape. Erratic boulders are sometimes also used as details in small park architecture, such as three Åland rapakivi granites on the pedestal of musicians in the fountain in Kościuszko Park (Figure 14).

Figure 14. Musicians in the corners of the fountain in the Kościuszko Park stand on abraded Åland rapakivi granite. The boulders here have supporting and aesthetic functions.

Large rock objects, characterised by an interesting shape or due to their colour, structure, and texture, are highly valued and are therefore often used as monuments or pedestals for displaying commemorative plaques. In such situations, erratic boulders play a cultural and informative role (e.g., [37,58,93–95]). There are at least four such erratic boulders in Pruszków: Småland granite (Figure 7), sandstone (Figure 15), Åland rapakivi granite in front of the DULAG 121 Museum (http://dulag121.pl/?lang=en [accessed on 10 February 2023]); (Figure 16), and a microgranite with a pegmatite vein.

Figure 15. A plate commemorating the 105th anniversary of granting city rights to Pruszków (1916) is attached to the sandstone. A geological object performs a culture-forming function.

Figure 16. Commemorative plate on the Åland rapakivi granite in front of the Museum DULAG 121. The rock plays culture-forming and aesthetic roles.

The lapidarium is an ex situ protective form of a stone object. Although it does not fit into the legal framework for protecting abiotic nature in Poland, it performs an important geoconservation function in relation to objects that are a testimony to the geological past and natural heritage and represent the region's above-average geodiversity. Appropriately directed interpretation of lapidary resources aimed at stimulating visiting tourists' awareness of the geological past of the area shows that abiotic nature should be protected and nurtured (e.g., [3,13,14,37,89]). It is difficult to expect them to support the protection of abiotic resources if they do not know and understand them. To address this, some geoscience researchers have expressed the need to integrate the local geological heritage into developing urban geotourism. Thus, the lapidarium, through its geo-interpreters/guides who shape positive attitudes among visitors, also plays an important educational and pro-environmental role.

6. An Urban Geosite in Pruszków

The purpose of the task, under which the geotrail was created and opened to visitors on 15 July 2022, was to develop the public space next to an outdoor gym. The project was aimed at initiating geotourism in Pruszków by creating a facility with high educational values and recreational-tourist infrastructure. The project promoter's intent was to facilitate a walk along this geotrail because it will provide an excellent lesson in geology, geography, environmental protection, and sightseeing. It will shape proper pro-environmental and ecological attitudes among residents and tourists and supplement their knowledge about the geological aspects of the area.

On the geotrail in Pruszków (Figures 17 and 18), the plan of which is shown in Figure 3, there are twelve Scandinavian erratic boulders in ten locations. Detailed information on geological objects is presented in Table 1. There are igneous rocks (boulders nos. 3–7, 10 in Figure 3) and metamorphic ones (nos. 2, 8–9). Both are derived from the Baltic Shield. There is also a sedimentary rock (no. 1) in the collection, which is derived from the layer covering the Baltic Shield. Both rock layers form the East European Platform in north-eastern Europe (Figure 19). The mother regions of the indicator erratics, present on the geotrail, are marked in Figure 20.

Figure 17. The geotrail in the vicinity of the Pruszków city bike stop and outdoor gym.

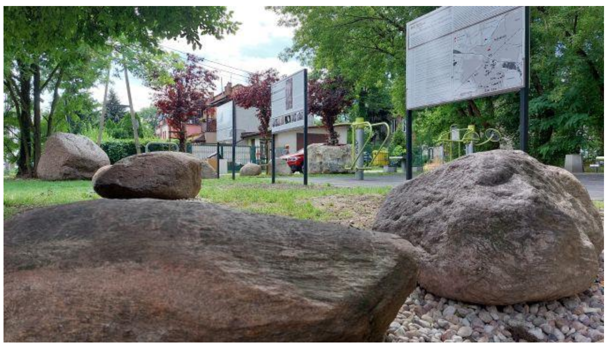

Figure 18. The geotrail consists of a collection of 12 erratic boulders and three double-sided informative boards.

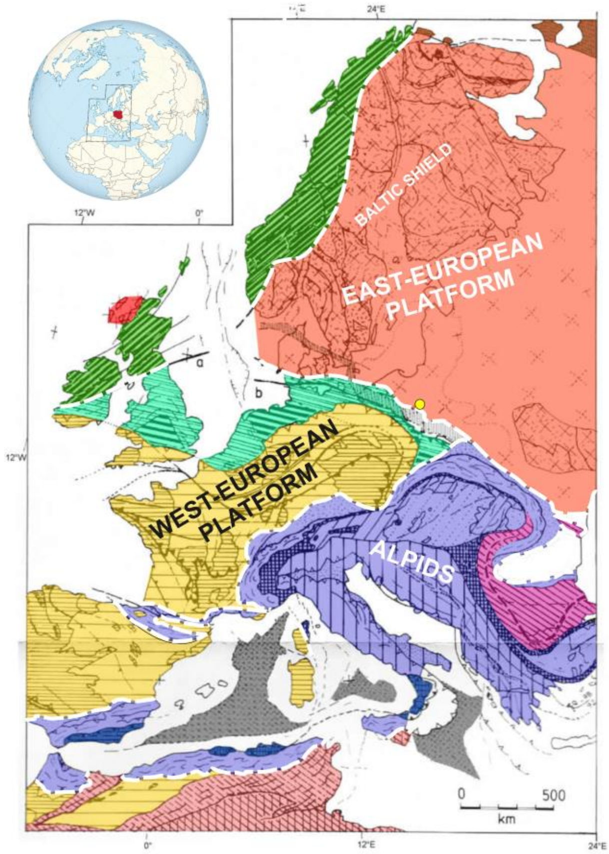

Figure 19. Schematic geological map of Europe. The yellow dot marks the location of Pruszków. The location of Poland and the area of a bigger map are given in the left upper corner.

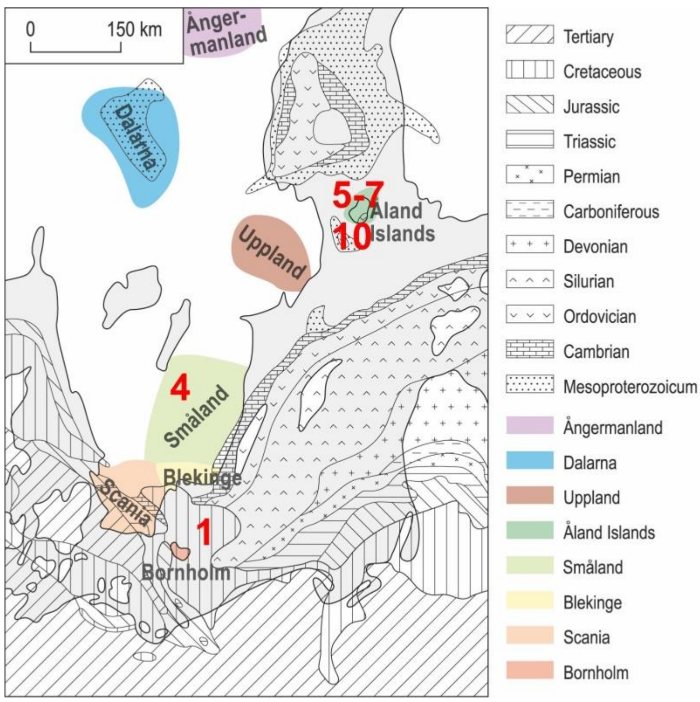

Figure 20. Source areas of indicator erratics located on the geotrail in Pruszków against the background of other main Scandinavian alimentation areas drawn in a very schematic form. Numbers according to Table 1.

As noted above, all erratic boulders within the geosite were deposited by the Scandinavian ice sheet during the Warta glaciation of the Central Polish complex around 130 ka BP. It was then that they began to emerge from under the melting mass of ice, lying on the surface of the still-frozen ground. These abandoned (imposed) large blocks of erratic boulders have rounded edges, which is characteristic of high-energy transport environments, e.g., in glacier tunnels.

Erratic boulders, currently exposed on the geotrail, have been surrounded by a ring of small pebbles from Mazovian rivers for aesthetic purposes (Figure 21). The pebbles are of the same age as the erratic boulders, i.e., they accumulated during the Wartanian glaciation. It is important for the recipient to have a complete and coherent picture of the geological past of south-western Mazovia from about 130,000 years ago.

Figure 21. Erratic boulder (No. 5) surrounded by a ring of pebbles from Mazovian rivers.

The collection of erratic boulders is complemented by three large, colorful, double-sided information boards presenting interpretative content in a way that is accessible to a layman (e.g., [96]). They have a similar layout and coherent editorial layer in common. Information boards present the following issues: "History written in stone" (Figure 22), "The importance of erratic boulders in Pruszków" (Figure 23), and "Erratic boulders in the city" (Figure 24).

Figure 22. Information board entitled, "History written in stone".

Figure 23. Information board entitled, "Significance of erratic boulders in Pruszków".

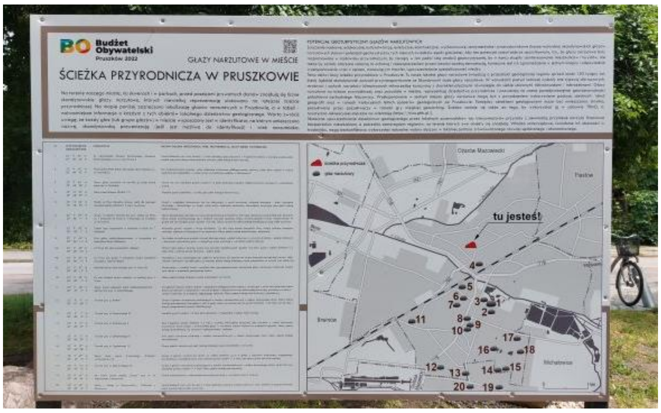

Figure 24. Information board entitled, "Erratic boulders in the city".

Each one has a QR code that directs the reader to in-depth content that did not fit within the board's limited space. After reading the information on the boards, the visitor will know what a rock is and what minerals it consists of, what an erratic boulder is, and how it got to Pruszków. There is a map of Pruszków on one of the boards, symbolically marking the locations of the erratic boulders remaining in the city. The adjacent table lists the most important features characterising these geological objects. The most interesting of them are shown in the photographs. Additionally, the elements of the boulder relief, which are a record of geological and geomorphological processes and are important from the point of view of educational significance, are clearly indicated on the photographs. A colorful leaflet is at the disposal of the visitor, which can be obtained from the promotion department of the municipal office.

A collection of erratic boulders is located in the vicinity of the Pruszków city bike stop and the outdoor gym (Figures 17, 18 and 21).

7. Overview of Erratic Boulders on the Geotrail

The basic features of the erratic boulders collected on the geotrail are presented in Table 1. The subsequent erratic boulders of the geosite area are presented in numerical order, starting with the erratic boulder no. 1 (Figure 3).

Boulder no. 1 is an opoka, a transitional sedimentary rock between carbonate and siliceous rocks, formed mainly as a result of the deposition of small remains of organisms built of silica: diatoms, radiolaria, and dissolved needles of silica sponges that, in large numbers, inhabited the Cretaceous seas (in the Mesozoic era). In the rock's non-homogeneous structure, there are remains of fragmented organic detritus, especially mussels and foraminifera, as well as numerous needles of sponges, which, with closer and more efficient observation, can also be seen in our object.

The opoka is a light gray or cream-coloured rock. The presence of additives often affects the rock's colour. The bluish tint comes from diffused pyrite. The most colouring element is iron, which, depending on the degree of oxidation, can cause a large variety of colours from yellow to red-brown. Colouring is also given by compounds of titanium, chromium, copper, and nickel.

Cretaceous sedimentary rocks form at the bottom of the southern Baltic Sea between Sweden, Denmark, Germany, and Poland (Figures 6, 19 and 20). From there, the Scandinavian ice sheet eroded a solid block of rock, incorporated it into its mass, moved it, and finally, in unfavourable climatic conditions (increase in air temperature), abandoned it to the south-western Mazovia.

Sedimentary rocks are not resistant to external morphogenetic factors that lead to both physical and chemical destruction of the rock. We are talking about insolation, temperature changes during the day and the calendar year, rainfall, and recently the rain of acidic sediments. One cannot forget about anthropopressure, i.e., a human being's negative impact. All of these factors cause the sedimentary rock to undergo rapid destruction. The rock that is present on our geopath has retained its very large size. This suggests that it was unearthed only relatively recently from near-surface subsoil deposits in the area. If it had been lying on the surface since the time of glacial deposition, i.e., about 130,000 years ago, it would not have been preserved in this size until our time. Therefore, it deserves even more careful and conscious protection. This is a unique object on a national scale.

Boulder no. 2 is a gneiss, a metamorphic rock whose exact Scandinavian provenance is impossible to pinpoint. It can only be determined that it was eroded by the ice sheet from the surface of the Baltic Shield (Figure 19).

This boulder has been included in the collection of geological objects due to its high aesthetic and educational values. A very nice and distinct eye structure of the gneiss can be seen on its side wall. It was formed in increased temperature and pressure affecting the previously formed igneous rock. As a result of the changed conditions, the feldspars (large bright crystals) melted and stretched (foliated) in the direction perpendicular to the force pressure. Feldspar nuclei were not completely melted/transformed, producing the image of the human eye and the eyelet name of the inequigranular texture. In terms of the crystals' arrangement, gneiss usually has a very directional, massive texture.

The surface condition of the boulder indicates it was directly deposited on the surface by a melting ice sheet. Under these conditions, it was subjected to the influence of morphogenetic processes its entire existence (i.e., about 130,000 years). The sculpture-forming processes were most effective in the conditions of the periglacial climate that functioned in the foreground of the shrinking ice sheet. In the dry, frosty air, grains of hard quartz from the outwash sands, spreading over large areas in the foreground of the retreating ice sheet, were blown over long distances. They encountered obstacles, e.g., in the form of an erratic boulder that underwent grinding, polishing, and smoothing of its side walls to such an extent that a sharp ridge was formed on the surface of the rock. This surface's form is perfectly visible in the top part of erratic boulder no. 2. There is another faceted rock on our geopath: erratic boulder no. 6.

The following geo-object, boulder no. 3—granite, is an equally excellent example of the effective and morphogenetic (sculpture-forming) influence of wind-sand-snow streams in periglacial climate conditions, recorded in the form of a ventifact. As can be seen, the faceted rocks can be developed regardless of the petrographic type. Here, next to each other, for educational purposes, metamorphic and igneous rocks are presented. The visitor may also encounter eolian corrasive rocks developed on sedimentary rocks, e.g., on sandstones.

Plutonic igneous rocks, represented by granite, were subject to cooling and crystallisation from the liquid phase (magma = silicate melt) or gaseous phase in the deep parts of the earth's crust. Since this process takes place slowly, the resulting mineral crystals are well-developed and clearly visible, which we call the open-crystalline structure. It is often medium- or coarse-grained.

The lack of characteristic structural and textural features of the described granite makes it impossible to indicate the Scandinavian source area from which the ice sheet eroded the rock block. We only used here the statement that the boulder comes from the surface of the Baltic Shield (Figure 19).

Erratic boulder no. 4 is Småland granite. This time, the exact source area of the rock can be indicated because it is the indicator erratic boulder. The rock comes from south-eastern Sweden in the Småland region (Figures 6 and 20). This fragment of the bedrock of today's Sweden was formed (solidified and crystallised) during the late phase of the Svekofen orogeny (1.96–1.75 billion years ago [B y.a.], [97]; 1.95–1.85 B y.a., [98–100]; 1.92–1.79 B y.a., [101]). This is also the age of the Småland granite on the geopath in Pruszków. The process of formation of granite—a plutonic igneous rock—is described above (rock no. 3).

When looking at the shape of the Småland granite, it should be noted that one of the side walls is formed by a glacial polish. This is an example of the effect of a destructive process called detersion, consisting of grinding and smoothing the surface of the rock while it was still in the bedrock over which the Scandinavian ice sheet moved. The morphological record may also have appeared on the surface of the rock while it was already being subglacially transported. The rock anchored in the foot of the ice sheet then rubs against the ground on which the ice sheet moves. A fragment of the flat/polished rock surface of the same origin, i.e., dating back to the times of subglacial transport, may be observed by a visitor on the geopath on boulders no. 5 and 7.

In addition, a trained eye will notice that the surface of boulder no. 4 is eolised. The erratic boulder was subject to the process of eolian corrasion, which was active in the conditions of a frosty, dry periglacial climate. As a result, we can observe a smoothed, polished rock surface. However, you can also see a well-developed corrasive microrelief manifesting itself with alternating microribs and microfurrows. Visitors to the geotrail can see fragments of side walls of the same origin on object no. 8–10.

Erratic boulder no. 5 is an Åland rapakivi granite—indicator erratic—having its maintenance area on the Åland Islands, located in the Baltic Sea between Stockholm and Helsinki (Figures 6 and 20). From this area, it was set off (eroded) from the ground by powerful glacial forces, incorporated into the ice mass, and dragged to the area of the Łowicko-Błońska Plain, which extends to south-western Mazovia. At the turn of the Paleoproterozoic and Mesoproterozoic eras (ca. 1.7–1.54 B y.a.), several plutons (plutonic magmatic structures) of granites with a characteristic rapakivi structure were intruded in the central part of the Baltic Shield. It was then that rock no. 5 was formed.

Looking at it closely, we will certainly notice numerous ovoids (Figure 25), i.e., circular mineral structures surrounded by a thin rim of another mineral. Inside each rapakivi structure is potassium feldspar (orthoclase). It is surrounded by a millimetre-wide band of sodium-potassium feldspar (plagioclase). In addition to feldspars, gray, round quartz crystals can be seen with the naked eye. It is worth taking the folder that accompanies the geopath in your hand because, in the photograph on the title page, the author has marked all of these important rock-forming minerals. The rapakivi structure is also indicated in Figure 2 of this folder.

The rapakivi structure has a high aesthetic value and is very easy to identify. The predominant red colour of Åland rapakivi granite was taken into account during the construction of stone sepulchral objects in prehistory [102], e.g., in Pałuki in north-western Poland [103]. In the Neolithic era (about 5000 years ago), megaliths were erected from erratic boulders. They were carefully selected based on the colour of the minerals (red potassium feldspar), which was important for emphasising the significance of the sacrifice.

The microrelief of this part of the surface of the rock block, which is oriented towards the visitor, proves that it is a glacial polish with post-glacial features. They are formed in the zone under the ice sheet (subglacial). If we see such structures in bedrock in a parent area, we gain certainty about the direction of a transgression (thrust/advance) of an ice sheet. This is a very important palaeogeographical indicator that scientists use to reconstruct the direction of the Pleistocene ice sheet's transgression. This indicator is also used in areas that are currently glaciated and subject to recession.

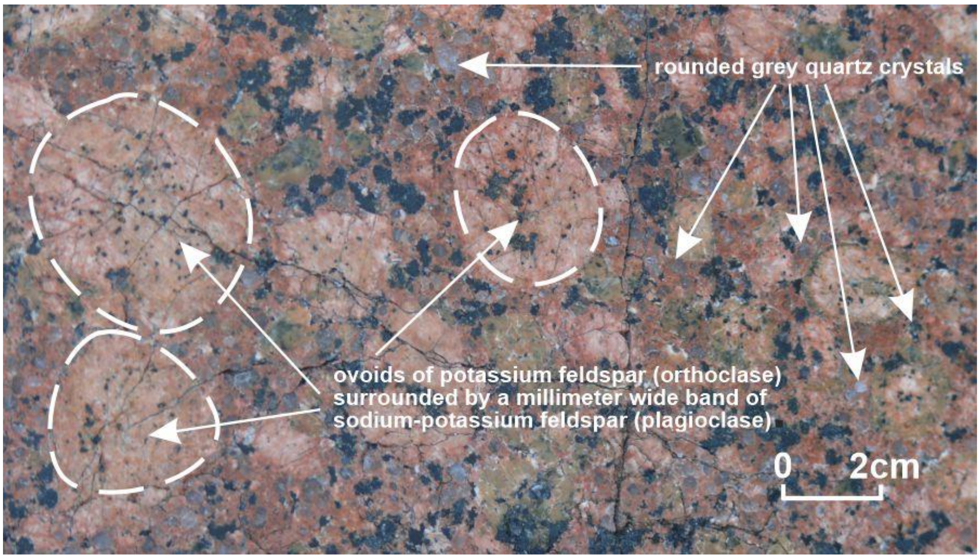

Figure 25. Details of the structure and texture of the Åland rapakivi granite.

Erratic boulder no. 6 is again Åland rapakivi granite—the indicator erratic—having its maintenance area in Åland Islands (Figures 6 and 20). Looking at the boulder's surface, we can see its eolisation, which we already know about from previous examples, i.e., smoothing and polishing of the side walls. Moreover, the erratic boulder must have been lying on the surface for a long time and was subject to the influence of eolian corrasion processes, which resulted in the formation of a classic facete. It is worth adding here that such a faceted rock (ventifact) could have only been formed in the conditions of stable (long-term) baric systems, thereby indirectly supporting our knowledge about the paleoclimate of this part of Mazovia.

Rock no. 7 is Åland quartz granite—the indicator erratic—originating from the Åland Islands (Figures 6 and 20). In the structure, we will not see feldspar ovoids; instead, we see perfectly formed round crystals of gray quartz, which are equally characteristic of this erratic. They can be seen with the naked eye. Looking at the boulder's silhouette, it is impossible not to notice that one of the walls is made of glacial polish.

Number 8 marks two gneisses, examples of metamorphic rocks whose surface of the side walls bears the record of the destructive process of eolian corrasion.

Erratic boulder no. 9 is a granito-gneiss, i.e., a rock that represents a transitional stage between an initial plutonic igneous rock and a metamorphic rock. The eoduct, i.e., granite in this case, did not have time to undergo the full metamorphosis process because it could, for example, get into the zone of reduced temperature or the side pressure subsided. The rock immediately crystallised, which we see today in the process of transformation stopped at a certain stage.

The surface of the granite-gneiss is slightly eolised, which means that the erratic boulder was subject to the destructive process of eolian corrasion in the frosty, dry environment of the foreland of the shrinking ice sheet. This impact on the described boulder was, however, very limited in time.

Among the two erratic boulders marked no. 10, we can successfully find Åland granite with a characteristic, brick-red coloration of potassium feldspars (Figure 25). The surface of the boulders has been affected by eolisation and so the walls are smoothed and polished in places.

8. Final Remarks

To sum up, it should be said that the geotrail is the first of its kind in Pruszków. These types of geosites can be extremely effective as fully fledged outreach tools capable of bridging the gap between Earth science and the lay public [89,96]). Therefore, the main goals for which this geosite was created, in relation to the inhabitants of Pruszków, had been:

- creating a place for education, recreation, and relaxation;
- getting to know the geological heritage of the region in which they live;
- raising awareness that the geological past of Western Mazovia is unique;
- building territorial identity with the region; and
- drawing attention to the problem of protecting abiotic nature (comp. [104]).

It is worth emphasising that, based on the lapidarium, geological knowledge (geointerpretation) is transferred to society [7,50,105]. This often occurs in conjunction with the biotic and cultural aspects of a given environment, which are, often unambiguously, conditioned by geological and landscape features (e.g., Pruszków was covered with the Scandinavian ice sheet in Pleistocene, leaving traces in the form of erratic boulders).

So far, the only person who geointerprets the features on the geosite is both the author of the project and this article (Figures 12 and 13). In the first year of operation of the geotrail, she conducted (pro bono publico) several geointerpretations of the geosite for school students. However, the intention of the project promoter is, of course, to use the high educational values of the geosite by the local geography teachers themselves. For this purpose, they were invited by the author of the project to methodological workshops (Figure 12 comp. also [98]. The geosite will also be made available for the general public during two or three "summer nature walks around the city", which the author (sometimes with her husband, geologist Dr. Ryszard Zabielski from the Polish Geological Institute National Research Institute) has been conducting (almost) annually since 2012. Her dissemination of geoheritage in the city attracts the attention of about 20–30 people each time. Both visiting the geosite and participating in summer nature walks are free of charge.

The collected erratic boulders represent all three petrographic types of rocks, which allows us to approximate the geological and geomorphological processes responsible for their formation. The rocks also bear the record of multiple processes archiving both the glacial stage and the stage after the ice sheet's melting. Three information boards placed along the geotrail and a folder that can be obtained from the Promotion Department of the Pruszków City Hall provide good substantive support. The QR code will make it easier to download more knowledge to your smartphone so that you can read the content later.

The geotrail was created for its recipients, i.e., all residents of Pruszków who want to learn about the region's geological past and the local Masovian geoheritage, who are interested in Pruszków's geoheritage, are sensitive to geodiversity and geoheritage protection, and who want to spend time outdoors in a unique way, deepening their knowledge about the history written in a stone.

According to (e.g., [106]), recipients can therefore be:

- people walking along the trail without any special motivation, learning about abiotic nature at the same time;
- people who are passionate about cognitive tourism but do not have specialised preparation; and
- professionals, experts, and others who are professionally connected to the earth sciences.

The third group of recipients is the expected and desired audience that understands the right interpretation. Geointerpreters, however, want their geological message to reach other groups as well [2,89,96]. Competent interpretation, however, requires a prepared audience that shows interest in the topic.

A special group of recipients is children who have little knowledge, but are curious about the world and have a large imagination [87]. In relation to this group, developed recreational and tourist facilities, interactive exhibitions, games, and plays referring to the history of the Earth are an excellent opportunity to implement the educational goals of geotourism.

Erratic boulders gathered on the Pruszkow geotrail perform a social function by making the recipients aware of the importance of preserving and protecting all elements of abiotic and biotic nature for their proper functioning. Erratic boulders have great potential for developing geotourism, including urban geotourism [8,107,108]. It is still a poorly developed branch of nature tourism in Poland, aimed at protecting geological and geomorphological heritages through the effective protection of geosites, extensive promotion of geological sciences, and promotion of educational and tourist functions [3]. Geotourism seamlessly uses the abiotic natural values of the area in local policy regarding sustainable social and economic development. It is the driving force for the economic development of peripheral tourist areas [1].

This local economic development in Pruszków could be even greater if new jobs were created in a business in the immediate vicinity, such as a small cafe. It would offer not only tasty ice cream to cool down with in the hot summer, but also leaflets and folders about the geotrail which would appeal to visitors. It would likely encourage many people to visit this lively corner of the city and learn about the area's geoheritage. Their environmental awareness would be strengthened by shaping appropriate pro-environmental attitudes.

9. Conclusions

It is worth emphasising once again that the role of a well-functioning geotrail (in our case, a rock garden/lapidarium), which through a rich program (e.g., organized summer nature walks around the city) and an interactive exhibition (comp. [4]), affects its surroundings and is invaluable in the sustainable development of the city/municipality/county. It co-shapes the image of a small homeland that develops elements of abiotic nature to perform urban (geo)tourism functions (e.g., geoheritage promotion) while maintaining the principles of nature protection. Orientation on innovation and its recognition as a component of local policies also shapes the conditions for a high-level quality of life.

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