



The Selected Erratic Boulders in the Świętokrzyskie Province (Central Poland) and Their Potential to Promote Geotourism

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Abstract

In the present paper, ten erratic boulders in the Świętokrzyskie Province (Central Poland) are described in detail, indicating their Scandinavian origin area, location, form of protection, petrographic type and morphology. In particular, special attention is placed on an evaluation of these boulders' current and potential significance for geotourism with the aim of promoting geotourism. The Devil's Stone from Kamienna Wola has a very high potential for promoting geotourism. Two other erratic boulders in Radoszyce and Wilków can promote geotourism to a lesser degree. The potential of the remaining boulders to promote nature-based tourism is medium or low. Some solutions are proposed to increase the importance of these erratic boulders in the sustainable development of the research area.

Keywords Indicator erratic boulders · Scandinavian origin · Assessment of geosites · Geotourism · Świętokrzyskie Province · Central Poland

Introduction

A boulder, according to Wentworth (1922), is a rock fragment whose shorter axis has a length equal to or greater than 256 mm. However, erratic boulders are commonly considered to have a shorter axis as long as 500 mm or longer. Also, rather

than axis length, the weight of the boulder is occasionally taken into consideration (Meyer 1999).

Scandinavian erratics found in Poland correspond with various types of rocks (igneous, metamorphic and sedimentary), although igneous plutonic and metamorphic rocks are dominant. The significant quantitative dominance of these rocks over sedimentary ones results from their higher resistance to destruction and from the geological structure of their source area in Scandinavia (e.g. Lundquist 1979; Ager 1980; Gorbatshev 1980, 1985; Gaál and Gorbatshev 1987; Andréasson and Rodhe 1990; Fredén 1994; Lundquist and Bygghammar 1994; Tuuling and Flodén 2001; Cocks and Torsvik 2005; Bogdanova et al. 2008; Hölltä et al. 2008; Wohlfarth et al. 2008). In fact, only 2% of large erratic boulders are sedimentary rocks (Schulz 1996, 1999).

Of this Scandinavian material, there are indicator erratics (Korn 1927; Lüttig 1958; Meyer and Lüttig 2007) that are easy to identify according to their structural and textural features (e.g. Sederholm 1891, Bartholomäus and Solcher 2002). These are derived from a single distinct outcrop in Scandinavia that may be described according to its geographical coordinates (necessary in the later analysis of the theoretical boulder centre (*Theoretisches GeschiebeZentrum* = TGZ, Lüttig 1958)). A relatively larger group of erratics are the ancillary ones (also called 'statistical' erratics; Vinx 1993). These are also easy to identify but have more than one mother region,

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or the area of the source region is much larger. Several representatives include Lower Palaeozoic limestone or Devonian dolomite. To determine the petrographic type of an erratic, it is not necessary to carry out detailed mineral-chemical analyses, as it is customary to use the common names of rocks (Meyer and Lüttig 2007; Meyer 1983; Górska 2000). However, rather than classifying the type of rock, the present research is focused on highlighting the Scandinavian origin of erratic boulders and/or their use for stratigraphic sediment recognition (e.g. Meyer 1990, 1993, 2000; Lüttig 1991; Górska-Zabielska 2008; Czubla 2015; Woźniak and Czubla 2015; Czubla et al. 2019).

Most large erratic boulders occur in situ, which means that their location has not changed since their time of glacial deposition. Such erratics indicate the prior presence of the Scandinavian ice sheet, which may be in fact considered as one of their most important scientific contributions.

Boulders exhibit certain morphological features on their surface that are indicative of their removal and/or transport by the Pleistocene ice sheet. These might be interpreted as a record of physical weathering processes or, in the present case, traction by ice, which produces rounded edges. This is a distinctive feature of glacial transport and applies to all glacial boulders. Sometimes, the surface of a boulder is affected by scratches, glacial striae (parallel grooves and/or crescent chatter marks) or glacial polish. These features could have arisen as a result of scouring against the crystalline bedrock when the boulder was being transported in the bottom layer of a moving ice-sheet. Or, these features could result from the abrasion of a boulder anchored in the bedrock by an ice-sheet sliding over it. The shape and orientation of microforms on an erratic boulder cannot be considered because erratics are redeposited. On the other hand, when such microforms occur on rocks in the source area, they can clearly indicate the direction of ice-sheet movements (e.g. Easterbrook 1999). In addition, traces of morphogenetic processes have been recorded on the surface of erratic boulders after the melting of ice bodies at the foreland of the retreating ice sheet (e.g. aeolian abrasion of the boulder surface visible as a smoothed surface, micro-ribs or a distinct edge; e.g. Ballantyne 2018).

In accordance with the Polish Nature Conservation Act of 2004, erratic boulders are protected by law as monuments of inanimate nature or (less often) as nature reserves. The legislation does not specify the criteria that boulders must meet to be protected (e.g. size, occurrence in situ, petrographic type, interesting shape, subject of legend and function). Because of the existence of this legal loophole, erratic boulders are often taken from their resting place and might later appear in stoneworkers' workshops (e.g. Piotrowski 2008; Chrzęszczewski 2009) or in private collections. However, these boulders are part of the geological heritage of a region and its geodiversity (Górska-Zabielska and Dobracki 2015; Górska-Zabielska et al. 2015). To preserve this geological heritage, an effort should be made to

conserve erratics in situ or place them in a lapidarium (Lat. *lapis*–stone) in the case that their movement is necessary (Meyer 1981, 2006, 2008; Krempien and Schulz 2008; Górska-Zabielska 2011; Reinicke 2012; Börner 2012, 2013; Górska-Zabielska and Dobracki 2015; Keiter 2017; Findlingspark Nochten; see, e.g. <https://www.findlingspark-nochten.de/index.php/de/>). The scope, concept and methods for assessing the geodiversity of a region have been presented in several papers (e.g. Kozłowski 2004; Gray 2013, 2018; Najwer and Zwoliński 2014; Zwoliński et al. 2018).

Erratic boulders are considered to be geosites (e.g. Urban 1990; Wróblewski 2000; Reynard 2004, 2012; Duraj et al. 2017; Keiter 2017; Grimmberger 2017; Köppe et al. 2018), i.e. objects of outstanding geological heritage. They can also be associated with ecological and cultural heritage (e.g. Göllnitz et al. 1996) and have high educational importance, as they can serve as regional focal points for both students and tourists. These are listed as part of Poland's geological heritage in the Central Register of Polish Geosites (see <http://geoportal.pgi.gov.pl/portal/page/portal/geostanowiska>).

Some erratic boulders are attractive tourist destinations because they are associated with regional histories and legends (e.g. Motta and Motta 2007; Grimmberger 2017), have interesting shapes, are multi-coloured or are large (e.g. Krause and Meyer 2018). This is especially true for boulders which are located along touristic routes or educational hiking paths. They are much less frequently geotouristic object in a region, although they often have such potential (e.g. Hoffmann and Dietrich 2004; Reynard 2004; Reynard et al. 2009; Brandes 2010; Górska-Zabielska 2015, 2016, 2020; Duraj et al. 2017; Chylińska and Kołodziejczyk 2018; Górska-Zabielska and Zabielski 2018; Woźniak et al. 2015).

Geotourism potential is described as the structural and functional georesources present in a given area that condition the development of geotourism. Recently, Ólafsdóttir and Tverijonaite (2018 and references therein) and Ólafsdóttir (2019 and references therein) cited numerous studies in which the geotourism potential of geological heritage was discussed.

In peripheral areas that are not commonly visited, the recognition of potential tourism attractions, including geological objects (Orłowska 2017), represents a great opportunity. Brozinski (2009) advises that a holistic and attractive experience must be provided for tourists, and a full story about the formation of the landscapes of geosites must also be provided to help tourists grasp their importance and develop a sense of awe. Geotourism as a rapid and dynamically developing new trend in tourism (Newsome and Dowling 2010; Dowling 2011; Ólafsdóttir and Tverijonaite 2018) attempts to find a new tourist offer, which will meet the individualised experiences specific to interests of increasingly well-educated tourists (e.g. Górska-Zabielska and Zabielski 2018).

In the Świętokrzyskie Province, Scandinavian material, mainly the gravel fraction, has frequently been the subject of

detailed investigations, including the Detailed Geological Map of Poland (e.g. Lamparski 1970, 1971; Lindner 1971, 1977). However, information on the occurrence of erratic boulders has rarely been published. The erratic boulders of Poland, including the Świętokrzyskie Province and other provinces, were first catalogued by Czernicka-Chodkowska in Czernicka-Chodkowska 1980. In addition, Urban (1990, 1997) inventoried the erratic boulders of the discussed study area with the aim of ensuring their legal protection. Also, Wróblewski (2000) took these boulders into consideration when discussing the issue of regional geodiversity protection.

Some erratic boulders in the Świętokrzyskie Province were recently described in tourism materials (e.g. Garus 2004, 2005; Sowa 2014). However, they have never been the sole subject of a scientific publication. The present research is a continuation of the work of the geography students of the Jan Kochanowski University in Kielce (unpublished MSc theses) to examine the potential of the geological heritage of the Świętokrzyskie Province for geotourism development.

Aims of the Study

The main goal of the present research is to estimate the potential of ten erratic boulders for the development of geotourism in the region.

Erratic boulders have potential as tourism destinations based on their recognition as important geosites (Migoń 2012; Duraj et al. 2017). However, it is first necessary that tourists and inhabitants become aware of their value. These boulders are, unfortunately, rarely noticed by residents and tourists and, hence, remain unexploited. Yet, awareness of geological heritage and its use in geotourism is increasing alongside hopes for improving the economic conditions of local communities (e.g. Xun and Tin 2003; Farsani et al. 2011, 2017; Dowling 2013). The transfer of knowledge from specialists/geointerpreters is essential to promote the development of geotourism, and the development of geotourism can contribute towards enhancing the well-being of the local communities adjacent to geosites (e.g. Pałka-Lebek and Kudła 2017). In this scenario, erratic boulders become geoproducts (Dryglas and Miśkiewicz 2014; Yuliawati et al. 2019) or, in other words, form part of the tourist offer and geoheritage of a site (cf. Reynard and Brilha 2018). Knowledge about these boulders may be imparted in the form of geointerpretation or storytelling (e.g. Hose 2006; Migoń and Pijet-Migoń 2017; Wolniewicz 2019).

Another partial aim of the present paper is to update the inventory of erratic boulders in the Świętokrzyskie Province. It is a pressing need because numerous previously unknown erratic boulders have been recognised or uncovered since the studies of Urban (1990, 1997), for example, during the construction of new buildings or sewer systems.

The present study is a continuation of the author's previous diagnostic studies (Górska-Zabielska et al., in prep.) in which it was found, for the first time, that the inventoried boulders were indicator erratics of Scandinavian origin (Fig. 1). In parallel with ongoing research, the shape and surface aspect of ten boulders and the environments that enabled their transport to central Poland were examined. Finally, the morphogenetic processes that affected these rock objects on the foreland of the shrinking Scandinavian ice sheet were identified.

In particular, the present article focuses on ten boulders selected according to the results of our previous studies. These boulders were selected because of their diversity, contemporary significance and uniqueness as natural heritage objects.

Study Area

The study area belongs to the Świętokrzyskie Province (Holy Cross Mountains Province in English) in central Poland. The Holy Cross Mountains (*Góry Świętokrzyskie* in Polish) is the main mountain range in central Poland and is built from Cambrian quartzites. The province contains Palaeozoic sedimentary rocks, which were folded during the Variscan Orogeny (Czarnecki 1919, 1938; Samsonowicz 1926; Dadlez 2001; Skompski and Żylińska 2015). The Palaeozoic core is surrounded by Permian-Mesozoic-Cenozoic rocks. To the south, the Świętokrzyskie Province is adjacent to the Nida Basin. It contains two tectonic units: the Miechów Synclinorium formed in Mesozoic rocks and the Carpathian Foredeep formed in Miocene marine deposits (Skompski and Żylińska 2015).

The late Cenozoic geological time, spanning the last 2.7 million years (Cohen and Gibbard 2011), is dated using marine isotope stage (MIS), that are alternating warm and cool periods in the Earth's paleoclimate, deduced from oxygen



Fig. 1 Location of analysed erratic boulders in the Świętokrzyskie Province in central Poland. The course of the MIS 6 ice margin (according to Marks et al. 2019) is shown

isotope data reflecting changes in temperature derived from data from deep-sea core samples (e.g. Wright 2000). Considering such dating, the Scandinavian ice sheet covered almost the entire Świętokrzyskie Province during the glaciations of MIS 16 (=Sanian 1) and MIS 12 (=Sanian 2), except for main peaks of the Holy Cross Mountains, where smaller or more extensive nunataks developed (Marks et al. 2016). Both glaciations are represented by two to three layers of till (Jurkiewiczowa 1968; Lindner et al. 2013). In this area, six erratic boulders (nos. 4–5 and 7–10 in Fig. 1) were inventoried. The traces of younger glaciations of MIS 6 (Odranian; Marks et al. 2018) were found at the NW and N margins of the study area (Fig. 1) with two till layers (Lindner 1970; Jurkiewiczowa et al. 1973). In this area, four erratic boulders (nos. 1–3 and 6 in Fig. 1) were inventoried. During the Vistulian Glaciation, when the ice sheet retreated to the northern part of Poland, periglacial conditions (with aeolian activity, among other processes) occurred in the study area (Mojski 1993).

Methods

The ten selected indicator erratic boulders were identified in the field. Available erratic rock atlases were consulted, including those of Meyer (1983), Zandstra (1999), Smed and Ehlers (2002) and Rudolph (2012, 2017). The photographs of the indicator erratics, taken by Matthias Bräunlich (see http://www.kristallin.de/s1/f_vanevik.htm#Anker1) were also used. The origin of some erratic boulders, such as the Småland granite, are indicated by the boulder size (Table 2), which is mainly an effect of bedrock jointing in the source area (e.g. Gorbatshev 1980; Gaál and Gorbatshev 1987; Johansson 1988; Rodhe 1992; Berglund et al. 1992; Lindh 2002; Scholz and Obst 2004). Cracks and fissures in the boulders can arise from the solidification of magma and/or tectonic movements. Notably, the Småland source area may not have experienced extensive weathering before it was glaciated (Smed and Ehlers 2002). The presence of blue quartz crystals has also been confirmed in this latter source region (Bartholomäus and Solcher 2002). Meanwhile, an origin in the Åland provenance is confirmed by the presence of large round potassium feldspars surrounded by a border of sodacalcium feldspars (Sederholm 1891) as well as clearly smaller, round and grey quartz crystals in the boulder. In addition, the basic dimensions of the boulders were measured (Table 2).

The next stage included an assessment (Table 3) of the ten erratic boulders according to the following criteria: scientific, educational, economic, conservation and additional values (Table 1). The grading method used in this paper was applied in similar previous cases (e.g. Bruschi and Cendrero 2005, 2009; Pereira et al. 2007; Reynard 2009; Kubalíková 2013; Kubalíková and Kirchner 2016; Baczyńska et al. 2018;

Górska-Zabielska 2020, in press). The evaluation criteria were slightly modified to the aims of the present work given the specificity of the study and region.

The category of scientific value was evaluated on the basis of four criteria: occurrence in/ex situ, type (indicator, ancillary or neither), number of features evidencing geological processes and prior descriptions in scientific or popular science publications. Notably, an indicative value of an erratic means that it is easy to recognise and is derived from a certain outcrop in Scandinavia. The category of educational value was also evaluated on the basis of four criteria: representativeness and clarity of geological features, quality of educational values (presence of an educated teacher/storyteller/guide), existing educational materials (e.g. leaflets, information boards) and existing educational trails. The category of economic value was evaluated on the basis of three criteria: accessibility, presence of tourist infrastructure (e.g. roofed structures, possibility of restaurants or hotel accommodations in the vicinity) and available local products and/or services. The category of conservation value was evaluated on the basis of four criteria: existing threats and risk of damage, potential threats and risk of damage, current state and legal protection status. The category of additional value was evaluated on the basis of three criteria: cultural value, ecological value and aesthetic value.

In previous studies, carried out as part of geography students' diploma theses, inhabitants of the region were asked through a diagnostic survey which of the above-mentioned criteria are most important for promoting geotourism. There are a few whose presence is desirable to assess the potential of erratic boulders that can promote geotourism. The surveyed mainly indicated that accessibility through educational materials and trails as well as aesthetic value attract tourists to geosites. Also, the presence of specialists who can provide knowledge or knowledgeable tours is welcome.

Description of Geosites

Kamienna Wola (Boulders No. 1 and 2 in Table 2 and Fig. 2a)

The first two boulders are associated with the geosite of Kamienna Wola. The first is the largest erratic boulder in the Świętokrzyskie Province: the Devil's Stone (Fig. 2a). It occurs in situ in the western part of the village of Kamienna Wola (Gowarczów administrative district). It is an indicator erratic composed of Småland granite that is most likely associated with outcrops in southeastern Sweden (e.g. Meyer 1983; Zandstra 1999; Smed and Ehlers 2002). Its surface is colonised by epilithic lichens, so it is not possible to determine the type of rock with absolute certainty. According to local communications, the presence of the boulder has attracted the interest of the local population since ages, who willingly

Table 1 Categories, criteria and scoring used for the evaluation of geotourism potential in erratic boulders in the Świętokrzyskie Province

CATEGORY	CRITERION	SCORE	0	0.5	1
1. Scientific value (max 4 points)	a - Location after ice thawing	Ex situ	Within 20 m from the excavation site	In situ	
	b - Type of erratic	Neither indicator nor ancillary	Ancillary	Indicator	
	c - Number of different features recognised in geosite	Only 1 feature	2–4 Features	More than 5 features	
	d - Scientific knowledge	Site not investigated	Scientific paper in national journal	Extensive knowledge of the site, published monography	
2. Educational value (max 4 points)	a - Representativeness and clarity of features	Weak representativeness/clarity of features	Medium representativeness, mainly for specialists	High representativeness of features, also for amateurs	
	b - Quality of educational example, educational usefulness	Weak example, weak educational usefulness of form	Good example but of limited educational usefulness	Very good example with high educational and geotourist usefulness	
	c - Existing educational products	Lack	leaflets, maps, web pages	Information boards, information next to the site	
	d - Existing forms of use for educational purposes (specialist tour, guided tour)	Lack of educational use	Site is a part of specialist tour (e.g. for students, geotourists)	Guided tour for the public	
3. ECONOMIC VALUE (max 3 points)	a - Accessibility	Restricted access (e.g. private area)	Unrestricted access, less than 1000 m from the car park	Unrestricted access, less than 1000 m from the public transport stop	
	b - Presence of tourist infrastructure (picnic area, shop, accommodation)	More than 10 km from the existing tourist facilities	5–10 km from the existing tourist facilities	Less than 5 km from the existing tourist facilities	
	c - Local products	Lack	Several products in a wider area	The place is a symbol for several local products	
	a - Existing threats and the risk of damage	Large existing threats and high risk of damage	Existing threat that may destroy the site	Low risk and almost non-existing threat	
4. Conservation value (max 4 points)	b - Potential threats and the risk of damage	Large potential threats and high risk of damage	Potential threat that may destroy the site	Low risk and almost non-potential threat	
	c - Current state	Continuous destruction of the site	Destroyed site but the action is taken to stop further destruction	No destruction	
	d - Legal protection status	Lack of legal protection	Existing legal protection	Effective legal protection in the form of a monument of inanimate nature	
	a - Cultural values (historical, archaeological, religious)	Lack	Existing cultural values but without a close connection with the site	Existing cultural values in close connection with the site	
5. ADDITIONAL VALUE (max 4.5 points)	b - Ecological value	Unimportant	Existing influence but without much significance	Different varieties of microbiota and lichens	
	c - Aesthetic value (number of colours, size of minerals, viewpoints, exposed position, volume)	0–1 colour, 0.25–2.3 colours, 0.5 – more than 3 colours	0 – fine-grained, 0.25 – medium-grained, 0.5 – coarse-grained with distinctly recognised minerals	0 – lack of observation points, 0.25–1.2 observation points, 0.5–3 and more observation points	
		0 – Position no exposed, 0.5 – position exposed	0 – Volume below 1 m ³ , 0.25 – volume between 1 and 2 m ³ , 0.5 – volume more than 2 m ³		

Fig. 2 **a** Devil's Stone (Kamienna Wola 1), the largest monument of inanimate nature in the Świętokrzyskie Province; **b** Boulder monument in Radoszyce with important cultural, historical and aesthetic significance; **c** Erratic boulder and monument of inanimate nature in Mniów in situ; **d** Two-part monument of inanimate nature in Wilków. Photograph by M. Górską-Zabielska 2016



settled in its vicinity. The boulder is protected by law as a monument of inanimate nature. In the register of the Regional Directorate for Environmental Protection (RDOŚ, for its Polish abbreviation), it is listed as item 429. A tourist trail (called Devil's Trail) leads to the Devil's Stone, which is also located in the vicinity of the springs of the Kamienna, Czarna and Drzewiczka Rivers (Bielawski 2016). A roofed structure intended for organising picnics and a field for sports competitions are also located at a distance of 50 m.

The second erratic boulder is present in the southern part of the village Kamienna Wola. It is a granite-gneiss without features of an indicator erratic. The boulder occurs in two uneven parts, which may indicate anthropogenic destruction. In the register of the RDOŚ, it appears as item 430. This monument of inanimate nature is accompanied by a plaque, which is rare in the study region, informing about the legal protection of the boulder.

There are numerous other erratic boulders in the village of Kamienna Wola and its surroundings. These are tangible evidence of the exceptionally abundant deposition of Scandinavian rock material in the area. It is likely that the name of the village (Pol. stony willingness) refers to the abundance of these rocks.

Radoszyce

The third erratic boulder, also formed from Småland granite, is located in the central square of the city of Radoszyce (Table 2). Presently, its shape is characterised by its rounded surface (the result of physical traction by ice) (Fig. 2b) and a surface of rock crack used to hang two plaques commemorating a local battle during World War II. Currently, the erratic block has important cultural, historical and aesthetic significance for the town's inhabitants.

Notably, in Radoszyce, there are a dozen other erratic boulders. They will be described by the author in a separate work.

Mniów

The fourth boulder in Mniów (Table 2; Fig. 2c) occurs in situ on the fringe of land between private agricultural areas. It is difficult to find the boulder because the top surface of the boulder is even with the terrain, and there are no signposts leading to it. The boulder is made of granite, with a very well-rounded surface. In the RDOŚ register, the boulder is listed as item 201. Despite its rank as a monument of inanimate nature, according to the oral information obtained from one inhabitant, the boulder does not arouse much interest among local inhabitants or tourists. Furthermore, it faces a high potential risk because it is located in a cultivated field where it can be exposed to destruction by large agricultural vehicles or may eventually be planted over.

Wilków

The fifth erratic boulder is found in situ in Wilków (Table 2; Fig. 2d) but has been broken into two parts. It is an indicator erratic composed of Åland quartz porphyry with a perfectly visible crystal texture. The boulder surface is partly covered by different varieties of lichens and mosses, which, incidentally, do not interfere with the perception of a typical red colour of the erratic. Both fragments of the boulder are protected by law as an inanimate natural monument (no. 135 in the RDOŚ registry). The boulder is potentially at risk of destruction because there is no signpost or information about the importance of protecting it and the local geodiversity.

Table 2 Basic information about erratic boulders under study in the Świętokrzyskie Province

No.	Geosite	In/ex situ location	Coordinates	Length (m)	Width (m)	Height (m)	Circuit (m)	Vol.* (m ³)	Weight* (t)	Type of glacial erratic
1	Kamienna Wola 1	In situ	51° 19' 42" N 20° 25' 27" E	6	3.5	2.5	16.5	27.46	75.51	Småland granite uncertain
2	Kamienna Wola 2	In situ	51° 19' 40" N 20° 26' 08" E	3.5	2.45	1	8	4.48	12.33	granite-gneiss
3	Radoszyce	Ex situ	51° 4' 26" N 20° 15' 34" E	1.2	1.1	1.4	3.95	0.97	2.66	Småland granite
4	Mniów	In situ	51° 1' 11" N 20° 28' 8" E	0.8	0.45	–	2.15	–	–	Granite
5	Wilków	In situ	50° 54' 48" N 20° 50' 58" E	2	1.8	0.8	4.9	1.51	4.14	Åland quartz porphyry
6	Lipnik	In situ	50° 56' 45" N 21° 30' 18" E	1.7	1.1	0.55	5	0.54	1.48	Siljan granite
7	Bardo	Ex situ	50° 45' N 21° 3' 22" E	1.5	1.3	1	4.9	1.02	2.8	Granite
8	Krepa	Ex situ	50° 43' 35" N 21° 20' 50" E	1.7	1.1	0.9	4.6	0.88	2.42	Granite
9	Chańcza	Ex situ	50° 38' 44" N 21° 5' 3" E	1.2	1	0.9	3.5	0.56	1.55	Åland rapakivi granite
10	Chinków	In situ	50° 21' 28" N 20° 50' 41" E	1.2	0.7	0.3	3	0.13	0.36	Småland granite

*Volume calculated from the formula $V = 0.523 \times a \times b \times c$ [m³] (Schulz 1964; Speetzen 1998), and weight from the relation $1 \text{ m}^3 = 2.7 - 2.8 \text{ t}$

Fig. 3 a Siljan granite and monument of inanimate nature in situ in Lipnik with glacial striae; b boulder in Krępa with aesthetic value; c erratic boulder and monument of inanimate nature in Chinków. Photograph by Górska-Zabielska 2016 (a and b), 2018 (c)



Lipnik

The sixth small erratic boulder is found in situ in Lipnik and is designated as a monument of inanimate nature. It is an indicator erratic composed of Siljan granite, whose source area is Dalarna in central Sweden (Meyer 1983; Zandstra 1999; Smed and Ehlers 2002). There is a set of glacial striae (not very distinct but visible) on the upper smooth surface of the boulder (Table 1; Fig. 3a). In the RDOŚ registry, it appears as no. 132.

Bardo

The seventh erratic boulder is found ex situ in Bardo. It is a fine-grained granite (Table 2) with a smooth surface in places and rounded edges. The entire surface of the boulder is colonised by lichens. In the top part of the boulder, there is a small rounded hole, which may indicate an attempt to break up the boulder into smaller fragments. It is designated as a monument of inanimate nature. In the RDOŚ registry, it appears as no. 398.

Krępa

The eighth erratic boulder is located ex situ in Krępa. It is a granite without the features of an indicator erratic (Table 2). It has a rather irregular shape, and some parts of its surface show aeolian abrasion (Fig. 3b). Traces of erosion (fine micro-ribs and smoothed surface, especially on protruding, convex surfaces) indicate that the boulder stayed in a dry and frosty (periglacial) environment at the foreground of the shrinking

ice sheet where the surface of the boulder was subject to destructive erosion processes (of wind-loess-crystallised snowflakes streams). The northern side of the boulder is covered with moss. The boulder is located in a private garden where it has an aesthetic function. In the RDOŚ registry, it appears at no. 435 and is designated as a monument of inanimate nature.

Chańcza

In Chańcza, there are two erratic boulders protected by law as monuments of inanimate nature registered as a single monument. They occur ex situ on the edge of the road in the eastern part of the village. The larger boulder is an indicator erratic composed of rapakivi granite from the Åland Islands. Having rounded edges, it is a good example of the final effect of physical weathering processes. Only this erratic boulder was taken into account in the assessment analysis (Table 2). The smaller boulder is gneiss with a glacial polish and indistinct glacial striae. Both boulders belong to smaller specimens in the described area (Table 2). In the RDOŚ registry, they appear as no. 222.

Chinków

The tenth erratic boulder is hardly visible because its upper surface is level with the ground. However, it is accompanied by a plaque indicating that it is a monument of inanimate nature (Fig. 3c). It is an indicator erratic composed of Småland granite with highly visible blue quartz crystals (Table 2).

Table 3 Evaluation of erratic boulders in the Świętokrzyskie Province

	1.SCIENTIFIC VALUE					2.EDUCATIONAL VALUE					3.ECONOMIC VALUE				4.CONSERVATION VALUE					5.ADDITIONAL VALUE				TOTAL
	a	b	c	d	sum	a	b	c	d	sum	a	b	c	sum	a	b	c	d	sum	a	b	c	sum	
Kamienna Wola 1	1	1	0.5	0.5	3	0.5	1	0.5	0	2	1	1	0	2	1	1	1	1	4	1	0.5	1.75	3.25	14.25
Kamienna Wola 2	1	0	0.5	0	1.5	0	0	0	0	0	1	0.5	0	1.5	1	1	1	1	4	0	0.5	0.5	1	8
Radoszyce	0	1	0.5	0	1.5	0.5	1	0	0	1.5	1	1	0	2	1	1	1	0.5	3.5	1	0	1.75	2.75	11.25
Mniów	1	0	0	0	1	0	0	0	0	0	0.5	0.5	0	1	0	0	0	1	1	0	0	0	0	3
Wilków	1	1	0.5	0.5	3	0.5	1	0.5	0	2	1	0	0	1	1	0.5	0.5	1	2.5	0	1	1.25	2.25	11.25
Lipnik	1	1	0.5	0.5	3	0.5	0.5	0.5	0	1.5	0	0	0	0	1	1	1	1	4	0	0	0	0	8.5
Bardo	0	0	0.5	0.5	1	0.5	0	0	0	0.5	0.5	0	0	0.5	1	1	0.5	1	3.5	0	0.5	0.75	1	6.75
Krępa	0	0	0	0.5	0.5	0	0	0	0	0	0	0.25	0	0.25	1	1	1	1	4	0	0.5	1	1.25	6.25
Chańcza	0	1	0.5	0	1.5	0.5	0.5	0	0	1	0.5	0	0	0.5	1	0.5	1	1	3.5	0	0	0.75	0.75	7.25
Chinków	1	1	0	0	2	0.5	0	0	0	0.5	1	1	0	2	1	1	1	1	4	0	0	0.25	0.25	8.75

For an explanation of abbreviations, see Table 1

In addition to its conservation importance (no. 228 in the RDOŚ registry), the boulder also plays a cultural role in the local community. According to a local legend, the boulder was once being transported in a cart by the villagers. However, the cart broke into two parts under its weight, and today, the boulder is still in the same place where this event took place. There is also a second legend saying that the boulder, which is embedded in the soil, is constantly growing.

Results of the Assessment Analysis

The ten above-described erratic boulders from the Świętokrzyskie Province (Fig. 1; Table 2) were evaluated (Table 3) to determine their potential for promoting geotourism.

In the category of scientific value, Devil’s Stone in Kamienna Wola (no. 1) obtained the highest score (3 out of 4 possible points) followed by the unnamed boulders from Wilków (5) and Lipnik (6). These boulders all occur in situ and are indicator erratics. None of the boulders received the maximum number (4) of points, mainly because of the lack of scientific information, as only four scientific papers have been published on erratic boulders in this region thus far (Urban 1986, 1990; Wróblewski 2000; Górska-Zabielska 2018).

In the category of educational value, the erratic boulders in Kamienna Wola (1) and Wilków (5) obtained the highest score (2 out of 4 possible points), mainly because they have high educational potential. The roofed picnic area in the vicinity of

the Devil’s Stone in Kamienna Wola, for example, can be used to conduct lessons in the field or for a shortstop during a walking tour along the tourist trail. Nine out of the ten boulders (apart from Mniów) described in this paper were mentioned in a prior tourism publication (Garus 2004, 2005) with a description of each boulder, including its size and arrival information. However, there is no simple petrographic description nor mention of its specific Scandinavian origin area. The location of these erratic boulders is also marked on maps, which may be viewed as another educational product (Bielawski 2016; Wróblewski 2000). However, none of the described boulders are accompanied by information or are located on the geotourist path. Also, erratic boulders are not generally included in the offer of widely available guide services.

In the category of economic value, three boulders scored 2 points each out of 3 possible points: Kamienna Wola (1), Radoszyce (3) and Chinków (10). Access to these boulders is easy, and there is tourism infrastructure (e.g. picnic place, possible accommodations, provisioning) in their immediate vicinity (up to 1 km). Unfortunately, no local products are associated with the boulders (e.g. the foundation of a building made of erratic boulders or a stone road) and none of the boulders are symbolically referenced by local products or arts and crafts.

In the category of conservation value, half of the ten boulders (1, 2, 6, 8 and 10) received the maximum score of 4 points, mostly because of the threats they are facing. For example, the

boulder in Mniów (4) is currently threatened with natural (complete overgrowth) and anthropogenic (agricultural vehicles) destruction. The two boulders protected by law in Chańcza (9) are slowly disappearing under rubbish. Also, a small fragment of the anthropogenically broken boulder in Wilków (5) may land in a local stoneworker's workshop (which is, unfortunately, a common case; cf. Piotrowski 2008; Chrząszczewski 2009) because it has been previously and evidently broken. Nine of the described erratic boulders are protected by law as monuments of inanimate nature. Only two of them (boulders nos. 2 and 10) are accompanied by descriptive plaques. Although *ex situ*, the boulders from Radoszyce (3) and Krępa (8) are protected because both are exhibited in the central square of the city and in a private garden, respectively.

Taking into account the category of additional value, two erratic boulders (1, 3) were strongly associated with cultural and historical values. Ecological values were noted in five cases (1, 2, 5, 7 and 8), as these boulders are colonised by epilithic microbiota with little effect on their weathering. Aesthetic values are mostly associated with Kamienna Wola (1) and Radoszyce (3) because of their size, and varied appearance and the possibility to closely observe them. None of the boulders received the maximum number of points (i.e. 4.5) in this category.

Previous research conducted by the author (Górska-Zabińska 2015 and 2020 in press) in the Wielkopolska region of western Poland similarly points to the unsatisfactory promotion of geotourism and erratic boulders. Only one boulder, St. Adalbert's Boulder, currently has great potential for geotourism. It is protected as a monument of inanimate nature since 1840. Other inventoried erratic boulders have little educational and cultural significance because of the lack of proper tourism infrastructure or difficult access; hence, these may only be able to promote geological or nature-based tourism to a limited extent.

Final Remarks

All erratic boulders inventoried in the present article can be presented as a new tourist offer by institutions promoting tourism and nature and, in this way, can be used to promote the sustainable development of the Świętokrzyskie Province.

For example, these boulders may be used for geocaching (see www.geocaching.com) or as sites with geocachets. Or, these sites may be characterised as geological attractions to generate greater tourist traffic, which can potentially provide economic benefits for local communities. To start developing this economic opportunity, it is necessary to provide a skilful interpretation of the geological history and features of the boulders in a way that enables their importance to be understood, specifically their importance for maintaining the local geological heritage, geodiversity and environment of a particulate site. Unfortunately, these aspects are little valued or understood by residents and, even worse, by the local government.

In the light of the present evaluation (Table 3), the potential of the erratic boulder (Devil's Stone) in Kamienna Wola (1) to promote geotourism is very high, and that of the boulders in Radoszyce (3) and Wilków (5) is also high (Table 4). All of these boulders are easily accessible, visible from a long distance and have a large size. These features favour the identification of traces of the geological processes that affected these objects at various stages of their functioning in the natural environment. Mostly, the boulders are protected, so the risk of their destruction is low. Also, they have cultural, historical and aesthetic values. Finally, geotourists can find accommodation and provisioning at a short distance from these boulders.

The potential of the remaining erratic boulders to promote geotourism is medium or low. This could change in the future if the boulders become more accessible (e.g. a tourist path is constructed) or are equipped with an information board and brochures/leaflets (e.g. Krienke and Obst 2009). Also, these erratic boulders could more effectively promote geotourism if they were the subject of local activities, such as educational paths (Kicińska-Świdorska and Słomka 2004; Baczyńska et al. 2018); storytelling in the Earth Sciences (Hose 2006; Migoń and Pijet-Migoń 2017; Wolniewicz 2019); local competitions for the most interesting poem or essay about the boulders; outdoor painting exercises for artists; geotourism rallies for families; or, finally, field games/excursions/lessons for school children (Rudolph 2014).

For local communities to take advantage of the geotourism potential of these erratic boulders, it is first necessary to

Table 4 Evaluation of the geotourism potential of erratic boulders in the Świętokrzyskie Province

Score		Geotourism potential	Numbers of erratic boulders
13.75-14.25		very high	1
11.25-13.5		high	3, 5
7.25-11		medium	2, 6, 9, 10
0-7		low	4, 7, 8

increase awareness among inhabitants and authorities of the location and geological importance of these boulders. Prior research carried out by the present author (Górska-Zabielska et al. 2019) indicates that this may be a long process, as the other geosites of the Świętokrzyskie Province (for instance, fancy rock formations, quarries and post-mining areas, karst sources, caves and formations related to river erosion), including the erratic boulders, are generally of little interest to individuals who see these objects every day in their neighbourhood. Unfortunately, the inhabitants of the Świętokrzyskie Province have no plans for the future development of erratic boulders or other geosites nor do they view these sites as an opportunity for improving their economic condition through geotourism.

Despite the results of the evaluation, the erratic boulders described herein could bring new visitors to their respective areas if local people had more examples of how valuing their geological heritage could improve their economy or standard of living, which would perhaps change their mindset regarding nature. Also, active assistance could be provided by local specialists or scientists in the form of information boards and/or leaflets describing petrographic gardens, such as this one: “Petrographic garden in Jezioro, Wielkopolski National Park” (2008, in Polish) and other brochures provided by the present author for other landscape parks and sites. Through popularising these boulders in lectures, articles, local walks or field games organised for schools and/or families, these erratic boulders could eventually come to represent important symbols or regional objects in the consciousness of local inhabitants. Finally, the authors hope that the present study, which indicates the scientific and geotourism value of selected geological heritage objects, can also contribute to disseminating knowledge about the glacial epoch in the Świętokrzyskie Province.

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