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Crenological features of Świętokrzyskie Voivodeship

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Abstract. Based on an analysis of 53 hydrographic maps at the scale 1:50,000, an inventory of crenological objects in Świętokrzyskie Voivodeship was made. A total of 462 were identified. Most (346) are permanent springs, followed by: 60 permanent springs with intakes, then 34 periodic springs, 10 spring groups, 5 bog springs, 3 mineral springs, 3 observed springs and 1 other outflow. Moreover, the studies revealed the diversity and specificity of the region in terms of crenology. Total discharge of all springs is small, having been estimated at 459.04 $dm^3 s^{-1}$. The most productive springs reach about 40 $dm^3 s^{-1}$ and only eight exceed 20 $dm^3 s^{-1}$. The total discharge of the ten greatest outflows amount to 258.6 $dm^3 s^{-1}$, which accounts for 56.3% of the output in Świętokrzyskie Voivodeship. In terms of the number of crenological objects, a clear difference between mountainous and highland areas was identified. In the Świętokrzyski National Park, 25 outflows were registered. Their total output is 6.5 $dm^3 s^{-1}$. At the same time, on the northern slopes of the Świętokrzyski National Park, 21 crenological objects with a total discharge of 5.5 $dm^3 s^{-1}$ were identified.

Key words:
crenological facilities, number and discharge of springs, Świętokrzyskie Voivodeship, Świętokrzyski National Park

Introduction

The Republic of Poland has variable coverage with hydrographic maps at a scale of 1:50,000. They contain a substantial amount of various information that allows a number of thematic analyses and an inventory of crenological objects to be performed (e.g. Choiński 1995; Baczyńska et al. 2004; Choiński 2009a, b; Choiński and Ptak 2018). Until the moment of edition of the maps, this type of study had not been possible. The vast resource of data included in the maps will certainly also contribute to research on numerous new issues not investigated to date.

Before the preparation of this paper, Choiński et al. used hydrographic maps at a scale of 1:50,000 for an inventory of springs over an area of 145,950 km^2 (equivalent of 46.7% of the territory of Poland). To date, the subject of studies has been the Oder River catchment (Choiński and Ptak 2009a, b), Przymorze River and Szczecin Lagoon catchments (Choiński 2009), and the lower part of the Vistula River catchment up to the Drwęca River catchment (Choiński and Ptak 2018). A total of 3,255 crenological objects were subject to the inventory. Their combined yield was estimated at 1.8435 $m^3 s^{-1}$.

Although the Świętokrzyskie region has full coverage with hydrographic maps at a scale of 1:50,000 (Fig. 1), it has not been thoroughly investigated in crenological terms, as confirmed by the scantness of the related literature. Moreover,

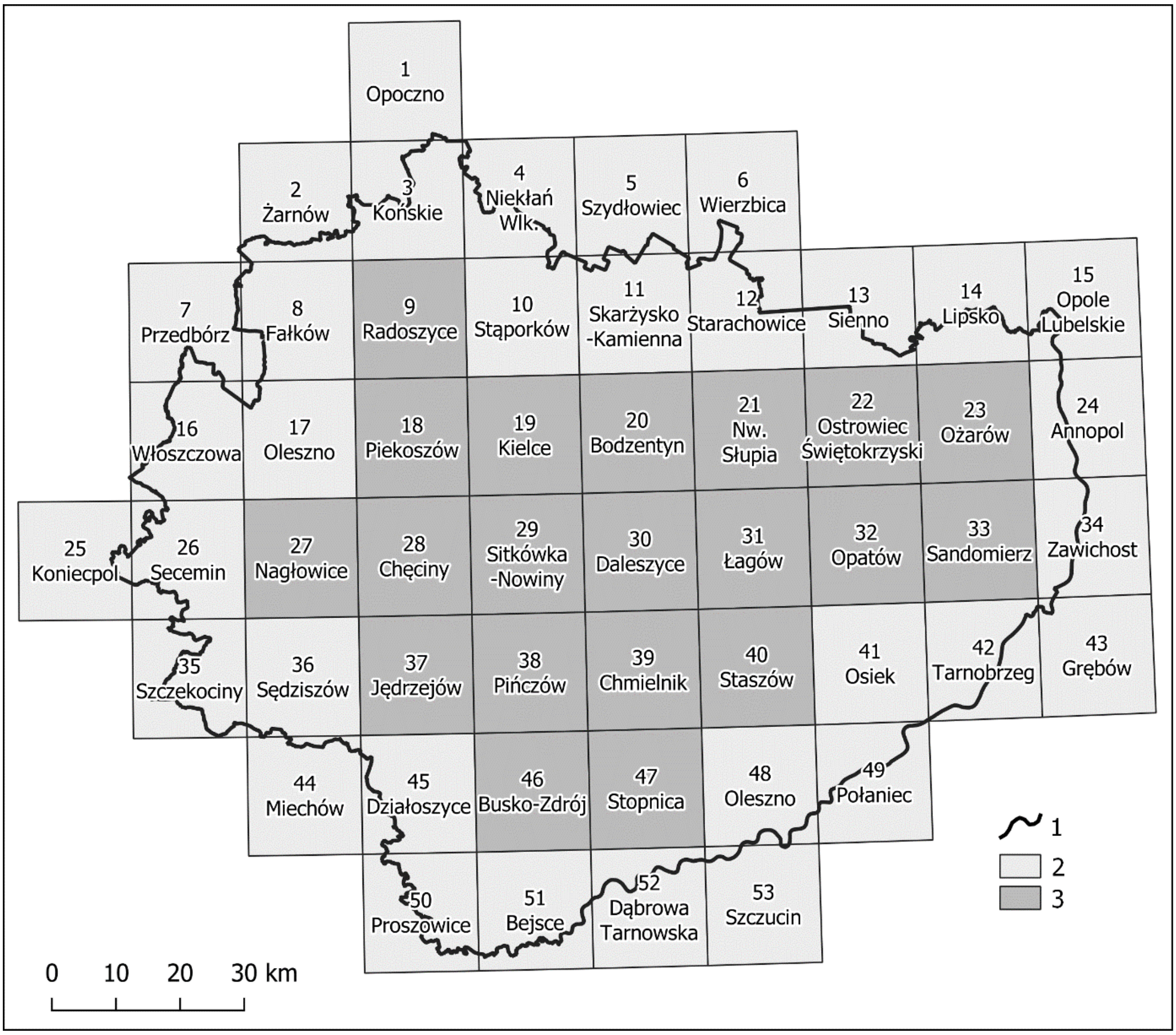

Fig. 1. Coverage of Świętokrzyskie Voivodeship with sheets of hydrographic maps at a scale of 1:50,000 1 – voivodeship boundary, 2 – sheets exceeding voivodeship boundary, 3 – sheets within voivodeship boundary
Source: own elaboration

related studies primarily concentrate on the Nida Basin and the Świętokrzyski National Park.

The scarce papers primarily concerning studies with local and regional character include: Berends 1834; Rogaliński 1972; Rogalińska and Rogaliński 1985; Chełmicki 1986; Kupczyk et al. 1994; Gągoł 1995; Gągol and Herman 1996; Herman and Gągol 1996, 2000; Biernat et al. 2000; Kupczyk et al. 2000; Ciupa 2006; Michalik 2006, 2008; Biernat et al. 2009; Suligowski et al. 2009; Chwalik-Borowiec et al. 2011; Ciupa et al. 2012; Ciupa and Suligowski 2012, 2017; Łajczak 2000, 2001, 2013; Michalik and Migaszewski 2012; and Ciupa et al. 2020. In addition to the aforementioned papers regarding areas within the Świętokrzyskie region, studies from other regions of Poland are available: e.g., Dynowska 1986; Jokiel 1994; Choiński 1995; 2009; Michalczyk 1997; Baścik and Pociask-Karteczka 2002; Michalczyk et al. 2004, 2015; Chełmicki 2006; Jokiel et al. 2007; Choiński and Ptak 2009a, b, 2018; Mazurek 2010; Chełmicki et al. 2011; Cieśliński and Leśniowski 2013; Siwek and Baścik 2013; Humnicki 2015; Moniewski 2016; Chabudziński and Brzezińska-Wójcik 2017; Łajczak 2017; Siwek and Pociask-Karteczka 2017; Bartnik and Moniewski 2018; Jokiel and Michalczyk 2021.

Due to the above, the objective of this paper is to inventory and investigate the specific and crenological diversity of the Świętokrzyskie region, which for simplicity is identified with Świętokrzyskie Voivodeship (precise boundaries of the administrative unit). Therefore, undertaking such studies within the aforementioned space seems fully justified.

Study area, materials and methods

In reference to large areas, hydrographic maps issued by the Head Office of Geodesy and Cartography (GUGiK) at a scale of 1:50,000 are a valuable source of information. Their drawbacks are related to their validity and credibility, and to the accuracy of field measurements and discrepancies resulting from the different terms in which they were conducted (at annual scale or at a scale of different years of mapping for the purpose of preparing successive sheets).

Unfortunately, the existing sheets cover only approximately 70% of the territory of the Republic of Poland. This study concerns Świętokrzyskie Voivodeship, because this administrative unit, as specified earlier, has been weakly investigated, but on the other hand has full coverage with such studies. Therefore, this paper covers a crenological analysis of a total of 53 sheets of hydrographic maps at a scale of 1:50,000. They are completely within the boundaries of the studied area for 21 maps, and partially for the remaining 32 as a result of their location at the boundary of the voivodeship (Fig. 1). In the case of sheets exceeding the boundaries of the voivodeship, the crenological analysis was conducted only in the part within the voivodeship. To simplify locating particular sheets within Świętokrzyskie Voivodeship, they were ascribed serial numbers. Numbering started from the sheet covering the northernmost part of the study area (Fig. 2). The area of Świętokrzyskie Voivodeship is 11,711 km^2 (Górski et al. 2018) and constitutes approximately 3.7% of the territory of Poland. The area is located in the belt of the Polish Uplands, within the Małopolska Upland (Richling et al. 2021).

The data obtained from the hydrographic maps are based on field research conducted primarily in the years 1998–2005. A large majority of measurements was performed in summer months, so the determined yields refer to that period, and, depending on the region, they can differ from the mean annual yield. The designation of crenological objects was adopted based on the rules of their presentation on the hydrographic map. The determination of yields was based on the following assumptions: for permanent springs and marshes with a yield of less than 0.5 dm^3 s^{-1}, a yield of 0.25 dm^3 s^{-1} was adopted; for marshes with expenditure greater than 0.5 dm^3 s^{-1}, a yield of 0.5 dm^3 s^{-1} was determined; complexes of permanent springs were ascribed 1 dm^3 s^{-1}; outflows were assigned a value of 0.1 dm^3 s^{-1}; springs with a range of yields were assigned the average value; confined, mineral springs, and those with no specified yield

Fig. 2. Owczary Reserve protecting the halophilic vegetation developing around a salt sulphur spring (Phot. E. Czerwińska 2021)

were assigned a value of 0.25 $dm^3 s^{-1}$; and periodical springs were assigned 0 $dm^3 s^{-1}$.

The analysis of hydrographic map sheets was carried out using the classic visual method. On its basis, dependencies on the components of the environment were established. In addition, GIS techniques were also used.

Results

The analysis of 53 hydrographic maps at a scale of 1:50,000 showed the occurrence of outflows on 33 sheets (Table 1, Fig. 3).

A total of 462 crenological objects were recorded in Świętokrzyskie Voivodeship. They are largely dominated by permanent springs, of which there were 346 (74.9%), followed by permanent confined springs – 60 (13%), periodical springs – 34 (7.4%),

Table 1. Number and yield of groundwater outflows determined within particular sheets and within the boundaries of Świętokrzyskie Voivodeship

Ordinal number	Sheet name	Number of crenological objects	Total yield [$dm^3 s^{-1}$]
3	Końskie	1	0.25
4	Niekłań	5	1.25
7	Przedbórz	1	0.25
9	Radoszyce	4	5.25
10	Stąporków	4	1.00
11	Skarżysko-Kamienna	6	1.75
12	Starachowice	4	1.00
16	Włoszczowa	1	0.25
17	Oleszno	3	24.30
18	Piekoszów	26	8.85
19	Kielce	35	5.50
20	Bodzentyn	49	14.40
21	Nowa Słupia	134	35.05
22	Ostrowiec Świętokrzyski	23	6.50
26	Secemin	1	0.25
27	Nagłowice	10	32.30
28	Chęciny	4	1.00
29	Sitkówka-Nowiny	21	9.56
30	Daleszyce	6	1.50
31	Łagów	16	11.00
32	Opatów	4	1.00
33	Sandomierz	4	1.00
35	Szczekociny	5	55.20
35	Sędziszów	8	26.90
37	Jędrzejów	1	0.00
38	Pińczów	24	14.50
39	Chmielnik	5	1.00
40	Staszów	18	49.85
42	Tarnobrzeg	1	0.00
46	Busko-Zdrój	10	10.37
47	Stopnica	17	113.75
49	Połaniec	2	0.26
50	Proszowice	9	24.00

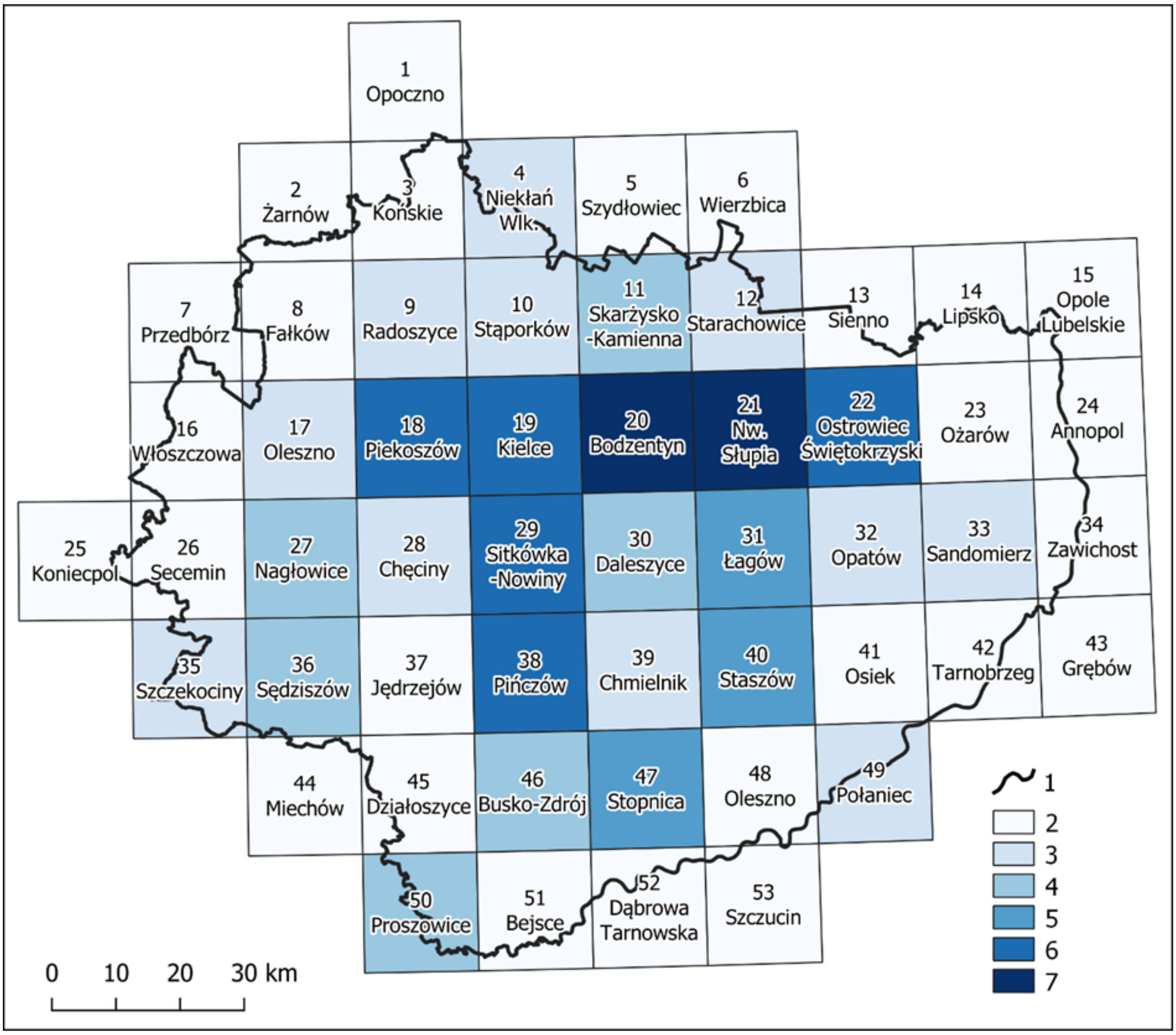

Fig. 3. Number of crenological objects within the sheets of hydrographic maps at a scale of 1:50,000 within the boundaries of Świętokrzyskie Voivodeship1 – voivodeship boundary; 2 – 0; 3 – 1–5; 4 – 6–10; 5 – 11–20; 6 – 21–40; 7 – above 40 Source: own elaboration

complexes of permanent springs – 10 (2.2%), marshes – 5 (1.1%), mineral springs – 3 (0.6%) (Fig. 2), 3 observed springs (0.6%), and only one outflow (0.2%). The number of crenological objects within the sheets and within the boundaries of Świętokrzyskie Voivodeship is presented in Figure 3 and Table 1.

It should be added that Świętokrzyskie Voivodeship is characterised by a varied and diversified topography. The highest point of this area is Łysica, which reaches 614 m above sea level. The lowest is the Vistula valley in the Tarłów Commune (128 m a.s.l.). Denivelations reach 486 m.

Likewise, the difference in height between the highest and lowest fixed sources is quite significant. The highest spring is located on the Holy Cross Mountains at an altitude of 527.5 m a.s.l. On the other hand, the lowest is the source in the Bałtów region (the slope of the Kamienna valley). It is situated at an altitude of 151 m a.s.l. The denivelations reach 376.5 m.

Discussion of results

Crenological objects are unique hydrographic elements connecting the underground and surface phase of water circulation. They are of considerable

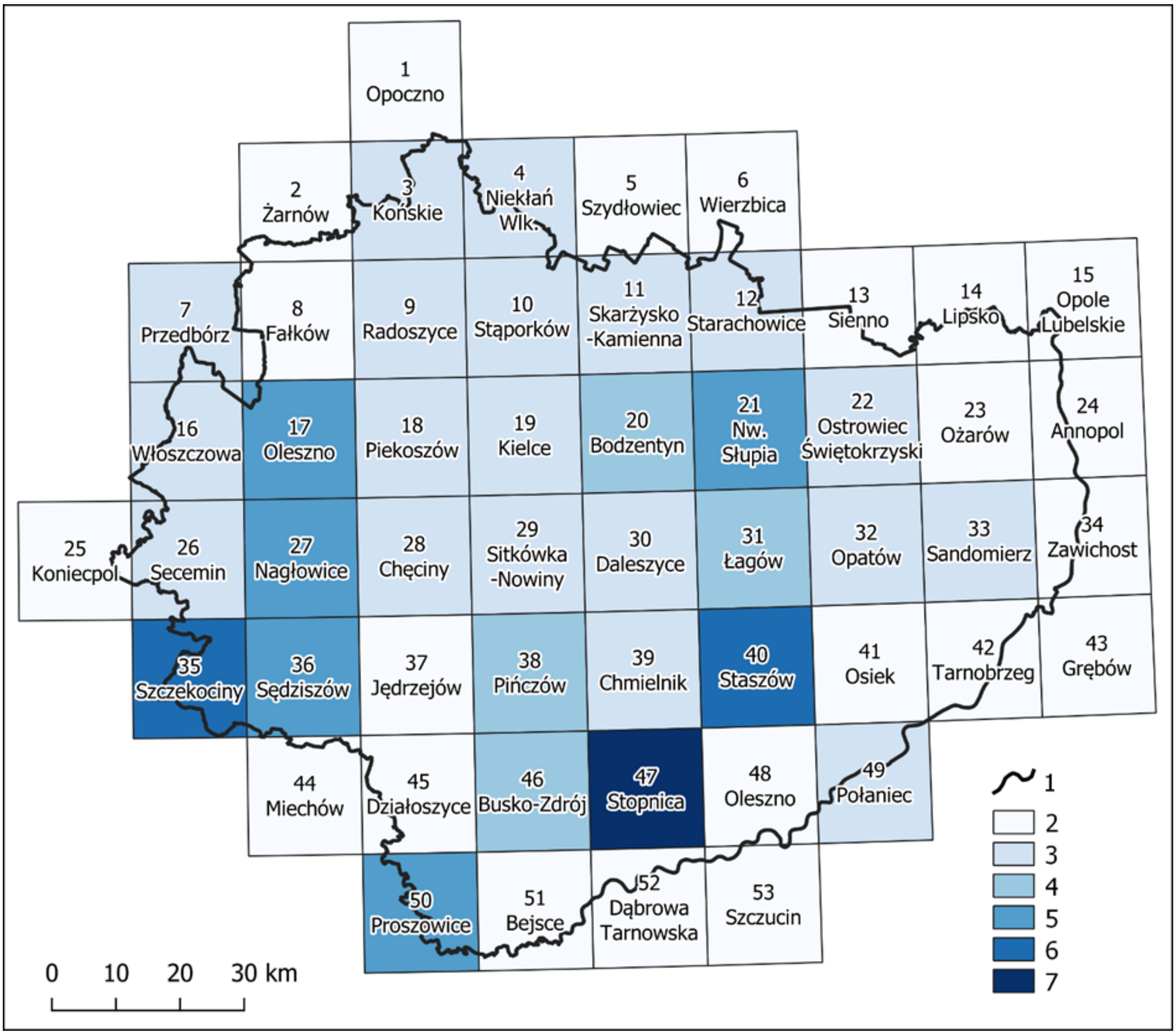

Fig. 4. Total yield [dm^3 s^{-1}] of groundwater outflows within particular sheets or their parts within the boundaries of Świętokrzyskie Voivodeship1 – voivodeship boundary; 2 – 0; 3 – 1–10; 4 –11–20; 5 – 21–40; 6 – 40–80; 7 – above 80
Source: own elaboration

and comprehensive importance for nature, landscape, culture, economy and science (Jokiel and Michalczyk 2021).

Unfortunately, they are subject to continuous transformations under the influence of both natural factors and increasingly strong human pressure. Due to this, the objects should be subject to considerably broader monitoring, and the collected data should be analysed and assessed. Such measures are necessary because they can justify urgent prevention and protection measures.

Due to the lack of continuity of the described phenomenon, we, like Choiński and Ptak (2009a, b, 2018), did not conduct interpolation. The intensification of the occurrence of crenological objects was presented within the map sheets. The obtained spatial distribution is highly variable. The highest numbers of crenological objects were recorded on the following sheets of maps covering mountainous areas: 21 – Nowa Słupia (134) and 20 – Bodzentyn (49). This finding is analogical to that of Choiński and Ptak (2009a, b). The authors pointed out that the highest number of crenological objects in the Oder River catchment occurs within the Szklarska Poręba, Szczytna and Wałbrzych sheets, in the catchment of Przymorze and the Szczcin Lagoon (Choiński 2009) on the Sianów, Choczewo and Kępice sheets, and in the lower part of the Vistula catchment (until the Drwęca catchment) within the

Nowe, Gniew, Brusy and Górzno sheets (Choiński and Ptak 2018). Differences in results emphasise the hydrogeological conditions, land relief and climate features of the discussed areas. The aforementioned paper is worth citing, however, because it is based on the same methodology as the present study.

Amongst the abundant available Polish crenological literature, research in the vicinity of the Świętokrzyskie region has been conducted by, for example, Michalczyk (1997). The author investigated springs in the upland area between the Vistula and Bug Rivers covering approximately 13,000 km2 – only approximately 11% more than the area of Świętokrzyskie Voivodeship. Approximately 1,550 springs have been recorded in the area, however, including approximately 1,230 springs functioning at the time, i.e. many more than the number of springs subject to the inventory on hydrographic maps within Świętokrzyskie Voivodeship. It should be emphasised, however, that next to the environmental distinctiveness of the compared areas, differences in the number of springs will result from different inventory methodologies. Nonetheless, like the authors of this study, Michalczyk (1997) found that the occurrence of springs there is very irregular. He observed them primarily in river valleys, which is particularly evident in the south-western part of the area between the Vistula and the Bug. As well as in valleys, he determined their existence in gullies dissecting plateaus with upper aquifers.

In the Świętokrzyskie region, the following sheets feature a greater number of crenological objects: 19 – Kielce (35), 18 – Piekoszów (26), 38 – Pińczów (24), 22 – Ostrowiec Świętokrzyski (23), 29 – Sitkówka-Nowiny (21), (Table 1, Fig. 3).

As well as the aforementioned spaces, areas completely devoid of crenological objects occur, e.g. on sheets: 8 – Fałków, 41 – Osiek, 48 – Oleśnica, 51 – Bejsce (Fig. 3).

The issue of the yield of crenological objects is interesting, both in individual terms and in terms of spatial distribution. The yield within particular sheets is presented in Figure 4 and Table 1.

In terms of yield, the mountainous area is not differentiated from the uplands. The yield of the outflows was determined based on the value ascribed to each crenological phenomenon occurring on a given sheet. The total yield for each sheet is the sum of all yields of outflows within a particular sheet. The greatest total yields were recorded for the following sheets: 47 – Stopnica (113.75 dm^3 s^{-1}), 35 – Szczekociny (55.2 dm^3 s^{-1}), 40 – Staszów (49.85 dm^3 s^{-1}), 21 – Nowa Słupia (35.05 dm^3 s^{-1}) and 27 – Nagłowice (32.3 dm^3 s^{-1}). It is worth emphasising that the total yield determined based on the five aforementioned sheets is 286.15 dm^3 s^{-1}. It corresponds with 62.3% of yield from the surface area of Świętokrzyskie Voivodeship. The sheet of a hydrographic map at a scale of 1:50,000 has a latitudinal extent of 15' and longitudinal extent of 10'. It presents an area of approximately 325 km^2. Therefore, the area of the five aforementioned sheets within the boundaries of the voivodeship is 1,467 km^2. It constitutes 12.5% of the surface area of the studied region.

Yields determined from the area of the aforementioned sheets from the Świętokrzyskie region are considerably higher than those provided by Choiński and Ptak (2018) in analogical research conducted in the lower course of the Vistula catchment, where the greatest yield was observed within the sheets Brusy (16.4 dm^3 s^{-1}) and South Elbląg (4.75 dm^3 s^{-1}), as well as Chojnice (4.6 dm^3 s^{-1}), or Choiński (2009) in research regarding the Przymorze River and Szczecin Lagoon catchments. The author estimated the highest yield within the sheets Choczewo (49.3 dm^3 s^{-1}), Sianów (13.25 dm^3 s^{-1}), and Kępice (11.20 dm^3 s^{-1}).

Higher yields were determined by Choiński and Ptak (2009a, b) in the mountainous areas of the Oder catchment, e.g. the Złoty Stok sheet (141.7 dm^3 s^{-1}) or the Szklarska Poręba sheet (131 dm^3 s^{-1}).

Obviously, the considerable differences in the presented results only confirm the vast regional diversity and hydrogeological conditions.

Springs in the Świętokrzyskie region with the highest yields reached values of: 40.0 dm^3 s^{-1} (35 – Szczekociny), 30.6 dm^3 s^{-1} (confined spring, 47 – Stopnica), 30.0 dm^3 s^{-1} (confined spring, 47 – Stopnica), 30.0 dm^3 s^{-1} (47 – Stopnica), 25.7 dm^3 s^{-1} (27 – Nagłowice), 23.9 dm^3 s^{-1} (36 – Sędziszów), 23.8 dm^3 s^{-1} (17 – Oleszno), 23.1 dm^3 s^{-1} (47 – Stopnica), and 19.0 dm^3 s^{-1} (40 – Staszów). A spring with a yield from 5.0 to 20 (average 12.5) dm^3 s^{-1} occurred in sheet 50 – Proszowice.

A total of 10 of the aforementioned outflows reach a yield of 258.6 dm^3 s^{-1}, which corresponds with more than 56.3% of the total yield of waters flowing from all the crenological objects of the Świętokrzyskie region.

In the Oder catchment, springs with the highest yields and those with yields greater than those in the Świętokrzyskie region were observed within the following sheets: Złoty Stok – mineral spring (63.5 dm^3 s^{-1}), Radęcin – spring (49.0 dm^3 s^{-1}) and Złoty Stok – mineral spring (44.7 dm^3 s^{-1}) (Choiński and Ptak 2009a, b). In the Przymorze River and Szczecin Lagoon catchments, springs show no substantial yields. That with the greatest yield is located within the Choczewo sheet (13.8 dm^3 s^{-1}) (Choiński 2009).

Considerably greater outflow yields were observed in the Lublin Upland and Roztocze by Michalczyk (1997) – for example, in the towns of: Zaporze (approximately 300 dm^3 s^{-1}, Por catchment), Malinie – 175 dm^3 s^{-1}, Abramów 140 dm^3 s^{-1} (Łada catchment), Stokowa Góra and Hutki – approximately 130 dm^3 s^{-1} each (Upper Wieprz catchment), Lute and Wierzchowiska – approximately 120 dm^3 s^{-1} each (Sanna catchment), Stryjno – 115 dm^3 s^{-1} (Giełczew catchment), Sołokije – 110 dm^3 s^{-1} (Sołokija catchment) and Świdry – 110 dm^3 s^{-1} (Łosiniecki Stream catchment). In periods of high groundwater tables, a yield of 100 dm^3 s^{-1} is exceeded, e.g. in Wąwolnica (Bystra catchment), Zakrzówek and Piotrowice (Bystrzyca catchment), Sobieska Wola (Giełczew catchment) and Husiny and Majdan Sopocki (Sopot catchment).

The average yield of a crenological object in Świętokrzyskie Voivodeship is low, slightly exceeding 0.99 dm^3 s^{-1}. The value is considerably higher than the 0.37 dm^3 s^{-1} calculated for objects in the Przymorze River and Szczecin Lagoon catchments based on the data of Choiński (2009).

It is worth mentioning that some of the springs enjoy popularity due to, for example, their location in the vicinity of popular tourist trails, folk beliefs regarding exceptional therapeutic values, or the flavour values of the water (Figs 5 and 6).

It should also be mentioned that, within the the Świętokrzyski National Park (ŚNP) with an area of 76.26 km^2 (Buchholz et al. 2020), 25 crenological objects were covered by the inventory, with a total yield of 6.5 dm^3 s^{-1} (sheets 20 – Bodzentyn and 21 – Nowa Słupia). Interestingly, 21 objects (19 permanent springs, each with a yield of less than 0.5 dm^3 s^{-1}, 1 marsh with a yield of 0.5 dm^3 s^{-1}, and 1 confined spring with an estimated yield of 0.25 dm3 s^{-1}), with a total yield of 5.5 dm^3 s^{-1}, are located on the northern slopes. They account for 84% of outflows and cover 84.6% of the yield from the area of the park.

The remaining four objects (3 permanent springs, each with a yield below 0.5 dm^3 s^{-1}, 1 confined spring with a yield estimated for 0.25 dm^3 s^{-1}) have a total yield of 1 dm^3 s^{-1} and are located on the southern slopes of ŚNP.

The results suggest that upland springs in the Świętokrzyskie region have greater yields and therefore differ from mountain springs functioning in Świętokrzyskie Voivodeship. Moreover, more than 83.3% of the crenological objects show very low

Fig. 5. Spring "Pod Dębem" near Staszów. On 8.01.2022, it had a yield of 0.2 dm^3 s^{-1}. The object was not marked on the hydrographic map (Phot. A. Zieliński 2022)

yields of below 0.5 dm^3 s^{-1}. The total yield of all 462 crenological objects in Świętokrzyskie Voivodeship is low and was determined at 459.04 dm^3 s^{-1}. The value is comparable with mean annual discharges of rivers such as 0.49 m^3 s^{-1} for the Sufraganiec at the Pietraszki profile (1994/2003, sheet 19 – Kielce), and 0.52 m^3 s^{-1} for the Świślina at the Rzepin profile (1976–1992, sheet 20 – Bodzentyn).

Due to natural and anthropogenic environmental transformations (e.g. Zieliński and Wałek 2012), combined with the passing of time since mapping for the purposes of the preparation of hydrographic maps, not all objects are functioning in the same way as in the inventory. This does not reduce the value of the hydrographic maps at a scale of 1:50,000. Some objects can disappear, and others join the ones subject to inventory, as confirmed by, for example, Figs.5 to 7.

It can be concluded that, as in the case of lakes (Choiński and Ptak 2008; Choiński et al. 2020; Choiński and Skowron 2021), there is a trend for the disappearance of springs or a decrease in their yield, as already signalled by, among others, Dynowska (1986) and Choiński and Ptak (2009a, b). Fluctuations of surface water tables may also be of importance (Zieliński 2013; Zieliński et al. 2013; Choiński et

Fig. 6. Spring in Kielce (Słowik) on 11.01.2022 with a yield of 0.29 dm^3 s^{-1}. The object was not marked on the hydrographic map (Phot. Z. Wojteczek 2022)

Fig. 7. Springs flowing from Cretaceous formations in the vicinity of the Warzyn Pierwszy village near Jędrzejów. The object was not marked on the hydrographic map (Phot. D. Wieczorek 2018)

al. 2020; Choiński and Skowron 2021). These may be the effect of, for example, the lowering of the first aquifer as a result of large-scale melioration works or excessive exploitation of water and of precipitation.

The inventory of crenological objects therefore appears justified, because it may prove useful in the determination of future changes. The above inventory is a kind of benchmark for future research – the assessment of these objects in terms of both yield and number. Although the limited framework of this study makes it difficult to talk about a catalogue of springs of Świętokrzyskie Voivodeship, the information contained here certainly provide a basis for one. Moreover, relatively complete knowledge on the location and yield of all crenological objects considered in hydrographic maps permits the selection of springs for further research, as well as for undertaking challenges aimed at supplementing and updating the content of hydrographic maps. After the analysis of underground outflows, e.g. on sheet 38 – Pińczów, 46 – Busko-Zdrój, no mineral springs were recorded whose existence is confirmed in the literature (e.g. Łajczak 2000, 2001, 2013; Chwalik-Borowiec et al. 2011; Różkowski et al. 2011).

Summary

The presented inventory of crenological objects is an example of the use of information contained in hydrographic maps at a scale of 1:50,000. This study regarding Świętokrzyskie Voivodeship involved crenological research in an area accounting for approximately 3.7% of Poland. The inventory covered 462 crenological objects on the maps, with a total yield estimated at 459.04 $dm^3 s^{-1}$.

Moreover, among others, outflows were recorded that were not considered in sheets of hydrographic maps (e.g. Figs. 5–7). This study supplements knowledge regarding the occurrence of crenological objects in the territory of Poland. It created a new space for comparison in the belt of the Polish Uplands within the Małopolska Upland, and new reference for further activities in the scope. The study results showed diversity and evidently emphasised the specificity of the Świętokrzyskie region. The highest numbers of crenological objects were recorded on sheets of maps in the mountainous area, e.g. sheets 21 – Nowa Słupia (134 objects) and 20 – Bodzentyn (49 objects). Moreover, differences in the yield appeared on the analysed maps. The greatest total yields were recorded within sheets 47 – Stopnica (113.75 $dm^3 s^{-1}$), 35 – Szczekociny (55.2 $dm^3 s^{-1}$) and 40 – Staszów (49.85 $dm^3 s^{-1}$).

The highest spring yields in the Świętokrzyskie region reached 40.0 $dm^3 s^{-1}$ (35 – Szczekociny), 30.6 $dm^3 s^{-1}$ and 30.0 $dm^3 s^{-1}$ (47 – Stopnica).

The occurrence of numerous crenological objects in the analysed area is the result of a combination of many factors, such as: large ground-level differences exceeding 400 m, exceptional diversity of lithology and stratigraphy of rock layers, i.e. from the Lower Palaeozoic to the Quaternary, the course of numerous faults, and large weathered covers in the top parts of the Świętokrzyskie Mountains. In the future, the task of researchers will be to classify the springs according to, for example: morphological location, water temperature, type of pipes leading groundwater to the source, lithological character of the formations, etc.

The study emphasised that the crenological aspect deserves more attention and should be subject to monitoring, because it is subject to transformations dependent on natural factors as well as the degree and trends of human pressure.

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Disclosure statement

No potential conflict of interest was reported by the author.

Author contributions

Study design: AZ, AC; data collection: AZ, AC; statistical analysis: AZ, AC; result interpretation: AZ, AC; manuscript preparation: AZ, AC; literature review: AZ, AC.

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