Dowgiałło, Jan

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Jan Dowgiałło (Poland)

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I Introductory remarks

Since the 15th century in which first signs of interest in groundwaters appear in written documents, the Polish territory changed many times both in size and in the position of its borders. Within the period between 1795–1918 the Polish independent state did not exist at all due to its partition between Austria, Russia and Prussia. After WWII Poland lost one third of its territory in the East and gained in the West. Therefore, the first decision to be made by somebody who wants to write about the history of hydrogeology, a science strictly linked to the territory, is to decide about the borders of this territory.

According to our opinion Polish hydrogeology developed not only on the territories now belonging to Poland, but also in areas both lost and gained within the course of history. This methodological assumption results in considering areas now belonging to the Czech Republic, Slovakia, Hungary, Ukraine, Belarus, the Baltic republics and Russia as well these, which before the end of WWII formed the eastern parts of Germany.

Another question to be considered was the fact that the Polish independent state did practically not exist for 123 years. During this period a considerable number of Polish hydrogeologists worked abroad, some of them with great success. Although achieved far from the Polish territory, this success, especially in the area of research methods, forms certainly a stage in the development of Polish hydrogeology and cannot be ignored while giving an outline of its development.

II Prehistory and early history (15th–18th centuries)

The times preceding the beginning of 19th century may be certainly called prehistory of modern science. This obviously concerns hydrogeology, which did not yet exist as a science, although many scientific observations often quite correct have been done and published in this early period.

The most ancient writers who gave some information about groundwaters were annalists or early historians. Almost every comprehensive work concerning the history of Poland was equipped with an introductory chapter containing a general description of the country, its borders, rivers, mountains and natural resources. The first and most eminent of them was Jan Długosz (1415–1480). In his *opus magnum*: *Annales seu Cronicae incliti Regni Poloniae* (*Annals or Chronicles of the famous Polish Kingdom* – first printed

1883–1887) he gives a detailed description of Poland's hydrography (in the introductory part entitled *Chorographia*) Writing about rivers he always mentions the location of their fountain–heads, sometimes including interesting details as for instance in the passage: (...) *Nida R. the fountain spring of which is in the Moskorzew village, at a certain section hides and flows underground and again in the forest of the Dzierzkowa willage* (...) *reappears* (...). In fact this is the first known record of Miocene gypsum karst phenomena present in the Nida R valley. Długosz is also describing rivers which have their sources in lakes. Sometimes his information is wrong like in the sentence quoted by Kowalenko (1975): *Aquae acidulae in Polonia absunt* (*There are no carbonated waters in Poland*).

Matthias Karpiga of Miechów called Miechowita is the author of *Chronica Polonorum* (*Chronicle of Poles*) (1519) in which several references to ordinary and mineral springs appear (Kowalenko, 1975). In another work *Conservatio Sanitatis* (*Maintenance of Health*) (1522) he included a part entitled *Tractatus de Aqua* (*Treatise on water*). Basing on Aristotelian ideas he discusses the origin of heat and cold in water and, following Avicenna, mentions the healing effects of application for drinking and bathing of waters containing iron, copper, aluminum and sulphur.

Another historian providing some hydrogeological information was Marcin Kromer (1512–1589). His highly informative work known under the title *Polonia* (the complete title in Latin is extremely long) was first published in 1575. In the introductory chapter the author mentions a. o. the presence of saline springs in South Poland (the Spisz province, now in Slovakia). In the same area there occur according to him waters which become *petrified* and build channels within which they flow. This is certainly a reminiscence of karstic caves appearing in the eastern part of the Tatra Mts. In the same area Kromer situates springs of water *harmful for the health*, producing *disastrous reeks* which kill animals drinking it or breathing in their exhalations. On the other side he writes also about springs of *warm water having a fragrance of sulphur* which heal ulcers and lichens both human and animal. In general, these early works informing about groundwaters show a mixture of superstition with some rational reasoning.

In the 16th and 17th centuries a somehow more scientific approach was represented by physicians and pharmacists who tried to apply mineral and thermal waters to heal diseases. In their works they could not ignore the springs of water they studied and noted sometimes important details concerning the shape and yield of the spring as well as the smell, colour, taste and temperature of water. Thus, these springs became the first *hydrogeological objects* which appeared in scientific writings.

Wojciech Oczko (1537–1589) was an outstanding physician, the official doctor of the royal dynasty, author a. o. of two treatises published in Polish: *Cieplice* [*Hot springs*] (1578) and *Przymiot* [*Syphilis*] (1581). Although both works concern mainly medical treatments with the application of numerous medicaments including thermal waters, considerable parts of them are devoted to considerations on the origin of these waters, the possible sources of their mineral content, the causes of their high temperature and their ways to

the surface. Oczko argues that even cold mineral waters may be called *thermal* as they lost their heat during their way to the spring. This is the reasoning which substantiates the common notion of *thermalism* or *thermal station* used in many European spas which in fact have nothing to do with real natural thermal waters. In fact, the only *thermal* springs mentioned by Oczko are those producing cold, sulphurous mineral waters at Szkło near Lwow, Mikulince near Trembowla, Swoszowice near Kraków and at Drużbak (Spisz province). Only the last water can be called thermal by present standards, its temperature slightly exceeding 20^0C.

As an humanistic erudite Oczko devotes much consideration to thermal waters in several European countries. Writing about some of them he wonders how coming from depths where coldness seems to dominate they become hot near the surface. Certainly, scientific consequence in this case is not his strong point.

Oczko is also discussing the ideas of Aristotle concerning the origin of *holy* (curative) waters. According to him: (...) *He* [Aristotle] *attributed their holiness to sulphur and thunder; we will attribute it not to their warming capacity, not to their sulphur smell, but to the fact that they greatly help to fight diseases which doctors and barber surgeons resigned to treat.*

Another famous physician interested in mineral waters was Erasmus Sixtus (1570–1635). He lived and worked in Lwów, and his main work concerns mineral waters at Szkło situated about 50 km NW of this city. His work *De Thermis in Pago Sklo libri tres* (*About hot springs in the village Szkło books three*) appeared first in Polish in 1617 (second, Latin edition appeared in 1780). Szkło (now in Ukraine) was once a fashionable spa often visited by King Jan Sobieski and his court. Mineral water is here linked to the presence of Miocene (Badenian) gypsum deposits and their reduction resulting in H_2S production. The work of Sixtus deals mostly with medical problems, but Book II is almost entirely devoted to considerations on the origin of mineral water and its chemical properties. All the then accessible methods of analysis (organoleptic proofs of water and its precipitate after evaporation) were used by Sixtus and he justly can be called *the first Polish balneochemist* (Kowalenko, 1984). He also gives a description of the then existing buildings and *technical* spa installations.

Jan Innocenty Petrycy (1592–1641) was the third member of the group of important Renaissance physicians interested in mineral waters and their medicinal application. In 1635 he published a book *About waters at Drużbak and Łęckowa, their use and diseases they are able to heal.* Drużbak (now Rużbachy Wyżne in the Spisz province of Slovakia) is known by its thermal (up to 23°C) carbonated water producing travertine walls which were exploited for construction. Petrycy writes about the mineral water as *being petrified*, but rightly attributes the origin of travertine to limestone *mixed* with water. His other interesting observation is that occasionally the clear spring water becomes *turbid like scum* and that this phenomenon is preceded by bad weather. Not knowing the notion of atmospheric pressure and its drop he, of course, could not explain what he observed.

Although the major part of Petrycy's work is devoted to medical prob-

lems and healing capacity of waters in both localities (Lęckowa was a nearby village as indicated by Majer, 1841), he considers in detail the *chemistry* of waters and devotes some attention to the shape and size of the timber lining of the springs. Although Petrycy's work was comprehensive and detailed, it has to be mentioned here that thermal waters at Rużbachy and at several other localities of the Spisz province were much earlier described by Wernher (1549). The question whether Petrycy knew the work of his predecessor remains open.

Kowalenko (1975) quotes two French authors who published their papers about mineral waters. Both concern Iwonicz, a renowned spa in the Polish Carpathians basing on saline waters with high methane content. One of these authors was supposedly K. L. Conradi, physician in ordinary of Queen Maria Sobieska (in fact the name of the actual author was Braun). In 1684 Conradi published in Latin an impressive volume (325 pages) entitled *Descriptio curiosa fontis cuiusdam inflammabilis et medicinalis in Polonia* (...) (*Accurate description of an inflammable and medicinal spring in Poland* (...)). Another, supplementary paper was published in French by the physician J. Ch. Denis: *Relations curieuses d'une fontaine découverte en Pologne laquelle entre autres propriétés à celles de prolonger la vie jusqu'a cent cinquante ans* (*Detailed accounts of a fountain discovered in Poland which besides other properties has that of extending life up to hundred fifty years*) (Paris, 1687). Although the author calls the spring *mont merveille* (*miracle mountain*), thus demonstrating elements of exaggerated marketing, both pathetic and improbable, he tries to give a scientific commentary to the phenomena only noted in the previous book like the combustibility of water, decrease and increase of the water level in the spring depending on moon phases and, last but not least, the healing potential of water.

Wojciech Tylkowski (1624?–1659), a philosopher and theologian is the author of 9–volumes work *Philosophia curiosa* (*A thorough Philosophy*). In the volume IX entitled *Meteorologia curiosa* (1669) there is one chapter dealing with springs, rivers and shallow groundwaters. Although not original and basing mostly on the ideas of Aristotle, Tylkowski is the first Polish author who gives a synthesis of the then existing opinions regarding groundwaters. According to him (see Piasecka, 1970) all rivers originate from the Sea. Their sources are filled with condensed vapor produced from Sea water evaporating in the underground. The condensation takes place close to the surface due to contact with cold rocks. The acceptance of this hypothesis after Aristotle enabled Tylkowski to explain the presence of springs in the mountains. He also did not exclude the existence of direct links of some springs with the Sea. In some lakes, according to him, pieces of ships drawned in the Sea pushed by water are found on the lake water surface.

Tylkowski was the first Polish author to explain the red color of water in some streams as originating from adjacent soil and rocks. However, his considerations about springs are much less convincing. He was interested only in peculiar cases, entirely ignoring ordinary springs. He thus writes about springs which are periodical, yield hot or unusually coloured water, about springs producing healing or harmful water, springs which react to thiefs and

illegitimate children, to perjury and ill manners of women thus helping to disclose socially inacepteble facts and behavior.

In another work *Scholarly conversations* (1692) Tylkowski specifies once again that seawater penetrating the Earth's interior forms numerous water veins. Water is evaporating, then condensing close to the surface and feeding the springs. A new idea regarding the disappearance of some springs is that dynamic processes in the underground may hinder the groundwater movement towards the spring. Answering the question why river waters are not saline he states that seawater from which rivers originate lose their salt content during migration through the Earth's interior.

The first half of the 18th century brings an important work of Gabriel Rzączyński (1664–1734), a Jesuit, one of the last Polish authors writing in Latin. In 1721 he published a big volume (488 pages): *Historia naturalis curiosa Regni Poloniae, Magni Ducatus Lithuaniae annexarumque provinciarum* (...) (*Thorough natural history of Poland, the Grand Duchy of Lithuania and adjacent provinces* (...)), a comprehensive description of the inanimate and animate nature in the territory defined by the title.

A spring according to the definition of Rzączyński is the beginning of a river. Spring water originates directly from the Sea. It is fresh being desalinated during its flow through the Earth strata. The author excluded the role of meteoric precipitations in the formation of ground–waters. He distinguished three types of springs: 1. flowing out like boiling water although it is cold, 2. with *trembling* water, 3. not discharging in the shape of a river but appearing as wells. He could not answer the question whether there are periodical springs in Poland (Piasecka, 1970).

Rzączyński worked till his death on appendices and corrections of his work. The addendum to *Historia naturalis* (...) appeared in print in 1742, after his death as: *Auctuarium historiae naturalis Regni Poloniae Magni Ducatus Lithuaniae ... etc.* (*Enrichment of the natural history ... etc*). This volume of 504 pages was an object of a detailed analysis of Balińska–Wuttke (1976) who has put special stress on Rzączyński's considerations about groundwaters. They are treated in Chapter 5 of *Auctuarium ...* entitled: *About mountains, springs, bituminous waters, sulphurous waters, waters changing into stone, boiling, healing, harmful, saline waters.* A part of this chapter is entitled *De Aquis qualitatum variarum* (*About waters of various qualities*).

Among springs Rzączyński distinguishes burning, stormy, seasonal springs. Burning springs occur according to him in the vicinity of the town Krosno (Carpathians) between Turaszówka and Potok which is the area where saline waters contain methane. In fact one of these springs is that at Iwonicz, studied and described by Conradi (1684) and Denis (1687). Stormy springs when set in motion produce rain. One of such springs is supposed to exist in Huszcza Wielka village in the Polesie province (now Belarus). Among seasonal springs the weather forecasting ones are known at Szkło near Lwów. During rains the two springs occurring there are stagnant, but in periods of good weather they seethe and eject water.

The classification of spring waters proposed by Rzączyński not necessarily follows the rules of logic. He distinguishes the following water types:

bituminous, sulphuric, nitrogenous, aluminous waters but also: petrifying, and causing petrification, frothing, medicinal, acidulous, noxious, blood–red, saline spring waters and lake waters.

This water typology is chaotic and the author realizes it writing for example: *Burning springs near Krosno contain also frothing waters called noxious; they froth in the cold state and never flow out (from the spring).*

Rzączyński must have collected his data very meticulously, although not always from credible sources. He quotes many localities in Poland and abroad, where springs and waters he writes about, appear. At Białobrzegi South of Warsaw there is according to him a spring producing small fishes, in particular during summertime and fall. An underground stream supposedly brings them to the spring. Sulphurous waters appear close to the salt mines at Wieliczka and Bochnia (which is true). Nitrogenous water appears at Kamieniec Podolski (now Ukraine) and in Lithuania, petrifying water occurs in the Spisz province (probably the author meant Drużbak) and in Supruszkowce (Podole, now Ukraine). Frothing waters occur in many places also in the Polish Lowlands (Reda, Kleszczewo a. o.) and in Volhynia (now Ukraine) *between Miedzyrzecz and Ostróg close to the villages Hulcza and Andruszówka, where frothing water sprays and throws out not only sand but gives back gravels thrown–in.*

Also other types of water appear in *Auctuarium* ... as linked to particular localities like acidulous waters at Krynica, Muszyna, Drużbak, Lubownia, etc., in the Carpathians, saline waters in Kałusz (now Ukraine), in the vicinity of Toruń and Szubin, at Stokliszki (Lithuania) etc. These facts are conform with reality.

It has to be concluded that although Rzączyński being a type of a book-worm rather than a field–worker did not verify all information collected, his work constitutes a summary of whatever was known (or imagined) about hydrogeology at his time.

Medical literature with only rudimentary information regarding the mode of appearance and data on the quality of curative waters and sometimes also some theoretical–philosophical considerations gets in the second half of the 18th century also a more hydrogeology–oriented trend and several papers devoted to the mere description of mineral springs and waters are published. Among them one of the first is an anonymous paper (probably by A. Krupiński) concerning *The description of mineral waters in general and in particular of that at Kozin located in the Polish Kingdom, district of Krzemieniec, Voivodship of Wolhynia* (1773).

A treatise by Krupiński (1775), although devoted to the *Description of diseases*, includes a chapter *About waters endowed with healing strength* containing numerous details concerning mineral water springs.

H. J. Crantz (1777) publishes a book concerning mineral springs of the Austrian Monarchy concerning a. o. the province of Galicia tweared away from Poland in 1772. The book contains descriptions of the already mentioned springs at Szkło and Rabka (now a well known health resort) as well as those of Nahojowice and Tustanowice. Also in 1773 an anonymous booklet appears (as reported by Czarniecki, 1977 the name of the author J. G. Morgenbesser

has been determined only in 1975) concerning mineral waters in Silesia (the present names of spas in which waters have been described are: Kudowa, Duszniki, Stary Zdrój, Jedlina, Szczawno, Świeradów). Detailed descriptions of the intakes including their size, shape and material used for construction are accompanied by the characteristic of *chemical* procedures applied to determine the water quality.

The first volume of the great work of Krzysztof Kluk (1739–1796) in which he considers groundwater appeared in 1781. Part II of this volume is devoted to water both common and mineral. On 66 pages he presents a physical characteristics of water adequate to the knowledge of the epoch ((...) *water particles must be round, which causes its ability to flow like grains of beans which contact each other only in one point* (...) . *Although water is one of the four elements it never appears in its elemental form, always including „alien" admixtures*, etc.). Kluk's classification of waters is very detailed and amazingly logical. Common waters are divided into *living* and *stagnant* with further subdivisions based on the form they appear (springs, lakees, marches etc.). Mineral waters are divided into cold (superior and more paltry), acidulous and thermal waters with many further detailed subdivisions. This classification deserves a comprehensive discussion which, however, would go beyond the framework of the present paper.

Kluk shares the opinion pronounced by the majority of his contemporaries that all groundwater which appears in springs and wells is of marine origin, but quotes also the rare and timidly expressed views underlining the role of atmospheric precipitations in groundwater forming. Interesting is his opinion concerning the origin of thermal waters as often connected with exothermic chemical reactions taking place in the underground. These reactions according to him occur mostly in the presence of sulfur and its compounds. The role of exothermic reactions in forming groundwater temperature is certainly exaggerated (Schoeller, 1962). It has, however to be underlined that Kluk took into account the high amount of heat produced per molecule of oxidized pyrite (FeS_2).

Gałkiewicz (1955) calls Kluk's book the first work in applied geology. This concerns to the letter the part devoted to water, in particular to groundwater. Kluk may be rightly qualified as the first Polish expert in practical hydrogeology, although the notion of *hydrogeology* appeared in the literature almost 120 years later (Krisztafowicz, 1899). His work contains a precise of qualitative and semi–quantitative analysis of water. This analytical part of the work is of course obsolete but shows details of the analytical *kitchen* in the second half of the 18th century. Kluk's suggestions regarding methods of water treatment, water prospection and execution of dug wells, ways of springs protection etc. are of value also for a groundwater practitioner of these days.

In 1789 the royal physician L. Lafontaine publishes a comprehensive book about thermal and cold mineral waters at Krzeszowice near Kraków, in 1790 appears a first modern chemical analysis of the *Main Spring* mineral water at Krynica. carried out by Hacquet. The paper by P. B. Hoppen about waters at Birże (Lithuania) appears in Wilno in 1791, while in 1792 S. B. Jun-

dził writes about saline springs and salt exploitation at Stokliszki (Lithuania).

The work of Michał Hube (1737–1807) published in 1791 was a textbook for military high schools. As pointed out by Piasecka (1970), his great contribution to science was the refutation of the long–living, commonly propagated and accepted theory that springs are recharged by seawater. Hube was the first in Polish scientific literature to state that ground–and spring–waters originate as a whole from atmospheric precipitations which sink into permeable soil and fissures. An aquifer has an impermeable bottom and in places where it intersects the surface water flows out in the form of springs. Therefore most of springs occur on mountains and hills slopes and in valleys where the lowest rock strata appear. *Springs therefore should be considered as groundwater mouths which supply water even if there was no rain for a long time* (Hube, 1791, p. 153). The groundwater table oscillates depending on the precipitation amountand this dependence decides about the number and yield of springs. Both these values are also dependent on the altitude of mountains which are always recharged by rains as well as melting snow and ice.

It is worth mentioning that by the end of the 18th century the famous scholar Alexander v. Humboldt prepared an expert evidence concerning the saline springs at Kołobrzeg (now Western Pomerania). According to Cramer (1892) who made a comprehensive analysis of Humboldt's work, it included the inventory of all wells at Kołobrzeg producing saline water, their yield and the salt concentration in water. Humboldt's conclusions concerning the possibility of salt production increase in the Kołobrzeg salt manufactory were optimistic enough to encourage the Prussian Treasury to buy it from the salt guild. Investigations of Dowgiałło (1965) who had at his disposal drilling material, only partly corroborated this optimism.

III The period of partititon (1795–1918)

In 1795 Poland lost for good its independence, becoming partitioned between Austria, Prussia and Russia. The lack of political freedom did not hinder the development of hydrogeology, although it was often exercised by foreign specialists.

Stanisław Staszic (1755–1826) is often called *the father of Polish geology*. His main work *About the Earth products* ... (1815) is a collection of 12 dissertations published earlier, concerning various regions of Poland. He was not only an outstanding scholar of the Enlightment era, but also a gifted organizer and administrator as well as a man of extreme diligence. Hydrogeology, however, doesn't seem to have been his beloved child and unlike other problems of both basic and practical geology, information about groundwaters is rather scarce in his writings. Nevertheless, he is an author of some ideas concerning mining hydrogeology (proposals for dewatering of coal as well as zinc and lead mines in the Kraków–Silesian area) The description of mineral springs by Staszic doesn't give much more information as compared with data done by previous authors, but he proposes a kind of a generalized chemical characteristics of Carpathian acidulous waters. The analysis defined as generally typical *with small variations* is presented in the form of a table where particular gases (CO_2, H_2S) and salts content is presented in grains per

20 pounds of water.

Systematic measurements of common water springs were done for the Warsaw area by G. G. Pusch (1844) and for the Tatra Mts. by L. Zejszner (1844). The interpretation of results obtained by Zejszner was an object of an animated polemics between both scientists

The development of spa medicine typical of Central Europe in the 19th century and at the beginning of 20th century (till WWI) on one hand and the progress in analytical chemistry on the other resulted in several hundred published chemical analyses of mineral waters. They were performed both by chemistry professors working at the universities of Kraków, Lwów, Wrocław, and Wilno and by practitioning pharmacists. Waters in renowned spas like Krynica, Iwonicz, Rabka, Szkło, Cieplice (Warmbrunn), Szczawno (Salzbrunn), Duszniki (Reinerz) etc. were analysed several times and the results published mostly in professional medical periodicals. Also waters in areas in which there were no spas were analysed. Particularly *productive* analysts were: A. Aleksandrowicz, J. Celiński, N. W. Fischer, A. M. Kitajewski, K. Olszewski, I. Radziszewski, K. Trochanowski, I. Radziszewski a. o. A detailed description of their achievements would go beyond the scope of this paper.

The interest in spa medicine resulted also in synthetic regional papers concerning the hydrogeology and chemistry of mineral waters. Works concerning: Lower Silesia by G. Mogalla (1802), Pomerania by C. J. B. Karsten (1847), Lithuania by A. F. Adamowicz (1851). Silesia by A. Hoennicke (1857) and Galicia by W. Szajnocha (1892) may be quoted in this respect.

In the last decade of the 19th century great importance has been attached to the water supply of big towns and industrial districts. Opinions concerning this question were worked out a. o. for Krakow by W. Szajnocha (1892), for Lwow by S. Olszewski (1895) for Gdansk by A. Jentsch (1899), for Lublin by N. J. Krisztafowicz (1899). Problems of water supply of the Upper Silesian industrial district were considered by Kunitz (1894) and Gellhorn (1894).

During the period of partition two national uprisings against Russia took place in 1830–1831 and in 1863. Both failed and their participants were trodden down by the tsar's oppressive system Many educated young persons had to emigrate and make their life abroad.

Ignacy Domeyko (1802–1899) took part in the conspiracy at the Wilno University, preceding the first of the above–mentioned uprisings and in the uprising itself. After studies in the Ecole des Mines in Paris he set out for Chile were he became university professor of chemistry and mineralogy. He terminated his career as president of the Santiago de Chile University.

As an extensively educated person Domeyko worked also as hydrogeologist. In 1847 he published a study concerning the hydrogeology of Santiago de Chile and its surroundings. He is also the author of ten or so papers containing hydrogeological descriptions and chemical analyses of Chilean mineral waters summarized in a monograph published in 1871.

Karol Bohdanowicz (1864–1947) was not a political emigree. He studied in Russia and became there professor of the St Petersburg Mining Institute. He did extensive geological and hydrogeological work in Russia (mainly in its

Asian part) as well as in other Asian countries. Except many important hydrogeological observations included in his excellent geological papers he published at least two separate papers devoted exclusively to hydrogeological questions (Bohdanowicz, 1890, 1915) Within the period 1915–1917 he was director of the Geological Committee (Geological Survey) of Russia. After WWI he worked in Poland as professor of the Krakow Academy of Mining and Metallurgy and after WWII was appointed director general of the Polish Geological Survey (State Geological Institute) keeping this post in the years 1946–1947 (Wójcik, 1997).

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