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On the criticality of minerals otherwise. New approach taking into account cultural, social and historical factors

Introduction

Raw material security, together with internal, military or health security, is a key component of national security. Mineral security is part of governments' industrial and economic policies and describes the balance between the need for mineral resources and the actual mineral resources available through both internal (extraction, processing) and external sources (import) (Galos et al. 2012). Ensuring national mineral security in the long-term requires establishing a coherent mineral policy, addressing, among others factors, the defining of which minerals play a crucial role for the economy and the population. Mineral safety

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is becoming one of the most important challenges of the 21st century (Vaughn 2007, 2011; Koroshy et al. 2010; Tiess 2010, 2011a, b; Lusty and Gunn 2014; Galos et al. 2020). Many countries have passed special laws regulating mineral security issues, including the USA with its *American Mineral Security Act* (AMSA 2019). The issue of mineral security is also included in strategic governmental documents concerning the mineral policy of individual countries. The criticality of minerals is most often considered in relation to the needs of the economy, especially its sensitive segments such as energy, the military and communications. However, when considering mineral security in relation to human needs, it can be shown that slightly different values and priorities matter. People can expect assurance of mineral security on many levels, e.g. access to health care services, including access to balneological minerals (Zglinicki and Szamałek 2021), the maintenance of historical and cultural heritage of their nation, especially in the field of material culture such as indigenous raw materials that have been used for centuries, and technologies to produce products and satisfy needs.

1. The concept and meaning of mineral criticality

A number of publications have raised the issue of mineral criticality (an extensive literature review on this topic is given by Schrijvers et al. 2020). Our study of the criticality of mineral raw materials was based on the analysis of documents (laws, regulations, communications) of a number of selected countries, European Union documents, official statistical data and published scientific sources. The research in this area is carried out by the authors within the framework of statutory works of the Polish Geological Survey. The obtained results may be used by the Polish state geological administration to prepare the strategic document 'State Mineral Policy'.

Various factors including geological, technological, geopolitical, social, and environmental factors are used in methodology to determine mineral criticality (Habib et al. 2016; Schrijvers et al. 2020). Terminology for classifying the importance of minerals to the economy and the population is not uniform and different terms are used in different countries. The role of minerals in the economy is underlined and indicated by using some dedicated terms, such as the following: scarce (deficit – Mazurek et al. 2021), critical, key, strategic minerals and mineral deposits of high public importance (Galos et al. 2018). Differences between the meaning of the term "critical" in English and Polish should be emphasized; Sermet and Auguścik (Sermet and Auguścik 2015) have already pointed this out. Despite these language difficulties, Radwanek-Bąk et al. (Radwanek-Bąk et al. 2018) proposed to use the term *critical raw materials* – for those whose chance of gaining (from both primary and secondary sources) is of high risk and their substitutability is low (in particular raw materials on the EU Critical List).

Each country determines its own criteria for assessing which mineral raw material (mineral commodity) is important (critical) to the country's economy from the point of view

of how to ensure the undisturbed production of goods and the fulfilling of social needs. Schrijvers et al. (Schrijvers et al. 2020) stated that the question "which materials are critical?" has not provided an unambiguous response, even if one has a specific nation or industry in mind. Galos et al. (Galos et al. 2020) has also presented an overview of the evolution of international methodologies in the recognition of certain minerals as critical and solutions introduced in some selected countries.

In the USA, the term "critical mineral" means any mineral, element, substance, or material designated as critical by the Secretary of the Interior (AMSA 2019). The US list of critical minerals does not include oil and natural gas or fossil fuels, water, ice and snow. By contrast, these mineral resources are considered critical in other countries. Traditionally, in US methodology, resources considered as strategic (critical) were those minerals which are crucial for military operations or important for the defense of the country (Minerals 2008). Until recently, critical minerals were mainly defined as those used in high-tech industries (semiconductors, computers, cell phones, tablets), defense and space industry.

Since 2011, the European Commission (EC) has been preparing systematic and updated lists of critical raw materials (including non-mineral raw materials) for the EU economy. The current list was published in September 2020 (EC 2020). It contains 30 raw materials (29 mineral commodities and natural rubber), which means a significant increase in the number of mineral raw materials in comparison to the first list from 2011 containing only 14 raw materials.

Poland draws on international experience in the field of the criticality of minerals and introduces its own solutions. Taking into account Polish conditions, Galos et al. (Galos et al. 2020) proposed the introduction of three categories of mineral commodities (the number of mineral commodities is given in brackets): key (42), strategic (25) and critical (17) minerals. A comprehensive characterization of critical mineral raw materials for Poland was provided by Baic et al. (Baic et al. 2015). Although most mineral commodities are thus far present in sufficient amounts in the discovered mineral deposits to ensure supplies for many years, their availability can be affected by many factors such as social constraints, politics, laws, environmental regulations, land-use restrictions, economics, and infrastructure (Schultz et al. 2017). Nowadays, the scientific community and industry are increasingly aware of the need for a new approach to the issue of the "importance" of mineral resources. Therefore, an extension of the criticality paradigm should be considered, including other mineral raw materials such as inorganic fertilizers or industrial minerals (Hayes and McCullough 2018), they also gave an extensive review of the literature on the issue of the criticality of raw materials. They dedicated their study to the criticality of chemical elements and they compiled the results of thirty-two studies published between 2005 and 2018. Hayes and McCullough (Hayes and McCullough 2018) took into account how many times each element was considered as critical and if the elements recovered as by-products were also identified as critical (this analysis also concerned the term critical over time and in geographical distribution). Hayes and McCullough (Hayes and McCullough 2018) concluded that three chemical elements (or group of elements) were most frequently identified as critical, namely rare earth

elements (REEs), platinum group metals – PGMs and indium (In). Also identified as critical were (in half of the analyzed studies): W, Ge, Co, Nb, Ta, Ga and Sb. The critical chemical elements indicated in this way can undoubtedly only concern highly developed economies, but in no way do they have a direct impact on the economies of the majority of developing countries (although the indirect impact is obvious, e.g. through the mass use of cell phones for payment purposes in these countries).

It is particularly important to determine the degree of dependence of the country's economy on foreign supplies (imports) of mineral raw materials. If the domestic economy imports more than 50% of the country's demand of a mineral commodity, it means that it is highly dependent. The risk of interruption to the supply of mineral raw materials to the national as well as to the world economy triggers additional impulses for the development of geological prospecting and documentation of mineral deposits and their development (Nieć et al. 2014). In order to ensure the development of the national economy, it is necessary to conduct systematic research to identify new prognostic and prospective areas of mineral deposits. Poland has a lot of experience in this field. The evolution of prospective resource research concerning the scope, data availability and use of information on deposits in the spatial planning and protection of prospective deposits was presented by Szamałek et al. (Szamałek et al. 2021).

2. The mining tradition and mineral resources of Poland

Poland is a country with a very long mining tradition. Here began the extraction of flint in the Neolithic period, followed by the extraction of rock salt from the Middle Ages to the present, and today, coal, oil, copper ore and other minerals are extracted (Table 1). The documented resources of mineral deposits in Poland (Szuflicki et al., ed. 2020) as well as the recognized predictive and prospective resources (Szamałek et al., ed. 2020) are still large. The number of documented mineral deposits (reserves) in Poland is as follows: 370 deposits of natural gas and methane CBM, 87 oil deposits, 162 deposits of hard coal, 91 deposits of lignite, 13 copper and silver deposits, 21 zinc and lead deposits, 50 deposits of chemical minerals, 13,546 deposits of rock minerals (Szuflicki et al., ed. 2020). This will allow maintaining of the extraction of many minerals over the coming decades. In the last few years, analyses have been conducted in Poland to answer the question of which mineral raw materials are basic/critical for the Polish economy. Galos et al. (Galos et al. 2020) proposed a list of mineral resources that are essential for the functioning of the Polish economy. By contrast, Mazurek and others (Mazurek et al. 2021, 2022) took into account the scarce minerals and the importance of different scales from supranational to local and the need to protect them for future generations. They have analyzed the national deficit of mineral commodities (classified as strategic and critical mineral commodities) against the volume of mineral deposits in Poland from which these commodities are obtained.

Table 1. Extraction of selected minerals in Poland in 2019 (taken from Szuflicki et al. 2020)

Tabela 1. Wydobycie wybranych kopalin w Polsce w 2019 roku

Mineral	Extraction	Unit
Natural gas	4.98	Bln m^3
Crude oil	0.94	Mln t
Lignite	52.86	Mln t
Coal	64.04	Mln t
Zn-Pb ores	1.51	Mln t
Cu-Ag ores	29.88	Mln t
Native sulphur	0.59	Mln t
Rock salt	4.06	Mln t
Dolomites	2.82	Mln t
Gypsum and anhydrite	1.07	Mln t
Sand and gravel	182.81	Mln t

3. Cultural, social, health and historical factors of criticality

During our studies, we have stated that there was a methodological lack how to describe some of the raw materials with regard to the following: specific deposits of fundamental importance for the realization of conservation functions (e.g. limestone from Dębnik); the historically proven importance of amber for material culture and the economy; the social role of balneological raw materials. The conclusions of our work are presented in our paper devoted to a different understanding of the concept of the criticality of minerals. The methodology for determining the criticality of raw materials varies between countries and is usually carried out by geological surveys. In Polish literature, there is no clear methodology for determining the criticality of raw materials. Therefore, it is necessary to open a wide discussion on this subject. Nevertheless, the authors believe that our rationale and arguments are sufficiently clearly presented in the paper. Therefore, it is necessary to use indicators other than those previously used in analyses to determine the criticality of mineral resources. However, is it possible to analyze the criticality of mineral resources in a different context than their importance for the most important branches of the economy? It seems that other important criteria for the criticality of minerals can also be adopted in a slightly different sense. Two World Wars took place in Poland, which led to the destruction of many historical monuments of material culture – secular and sacred architectural objects important for the Polish national culture. Currently, the reconstruction or conservation of these historic build-

ings is being undertaken. Nowadays, monument conservators require the use of original rocks for the renovation and conservation of churches, castles, historic defensive town walls etc. Very often, the building material in the Middle Ages came from local, small quarries located in the near vicinity. An example is black bituminous limestone (called black marble) from the Dębnik deposit located near Krzeszowice to the west of Kraków. This limestone was used extensively throughout the heyday of the Baroque, in the seventeenth and eighteenth centuries to decorate many sacred and secular buildings throughout Poland, especially in its southern regions (Figure 1).

Fig. 1. (A) A stoup made of the black Dębnik limestone, photo M. Florczyk (Florczyk and Smoleńska 2012); (B) Baroque tombstone in the cloister (Dębnik limestone), photo D. Szrek (Szczepanik 2015)

Rys. 1. (A) Kropielnica wykonana z czarnego wapienia dębnickiego, fot. M. Florczyk; (B) Barokowy nagrobek w klasztorze (wapień dębnicki), fot. D. Szrek

The operation of this quarry ended several decades ago (in the second half of the 20th century) due to the depletion of resources. For the restoration of these monuments, this "black marble" is necessary. Other black marbles available from foreign sources are different from the Dębnik limestone. Black limestone from Dębnik was the only marble-type limestone found in Poland. Therefore, the Polish Geological Institute (PGI) has been carrying out a special research program between 2017–2020 aimed at inventorying all former mining sites and indicating where and under what conditions it will be possible to extract the rocks used in the past. Small amounts of limestone from Dębnik still remain in the deposit. For environmental reasons, it is not possible to return to open pit mining and therefore an underground mining option is considered. In this case, the criticality of the raw material (black marble) is due to historical and cultural reasons instead of being critical for economic processes. One of recommendations of the PGI study is to allow the extraction to Polish geo-

logical survey, without a mining license, of selected, small parties of critical rocks essential for monuments restoration.

The demographic structure of Poland and Europe is changing alarmingly (Eurostat 2020). The aging of society and civilization diseases have created and will continue to create the need for increasing the use of natural balneological resources in the treatment and the prevention of civilization diseases. In recent years, there has been a noticeable increase in interest in spa treatment and spa or wellness services as recreational activities (a form of physical activity undertaken for the purpose of relaxation and the renewal of psychophysical forces), mainly among younger people (Zglinicki and Szamałek 2021). The social demand and the development of balneotherapy and spa prophylaxis will require securing the resources of curative raw materials – curative medicinal waters, medicinal gases (H_2S, CO_2 and Rn) and therapeutic muds (peloids). According to Szuflicki et al. (Szuflicki et al. 2020), the number of thermal, therapeutic and brine deposits in Poland (Figure 2) was 142, including therapeutic waters (109), thermal waters (32) and brine (1). These significant proven medicinal mineral reserves and their prospective and prognostic resources will help improve the health of the Polish people. This also requires that these deposits be protected from other development.

It is important to emphasize that the most important critical resource is water. It is what determines the existence of biological life. With the exception of a few cases, water is not

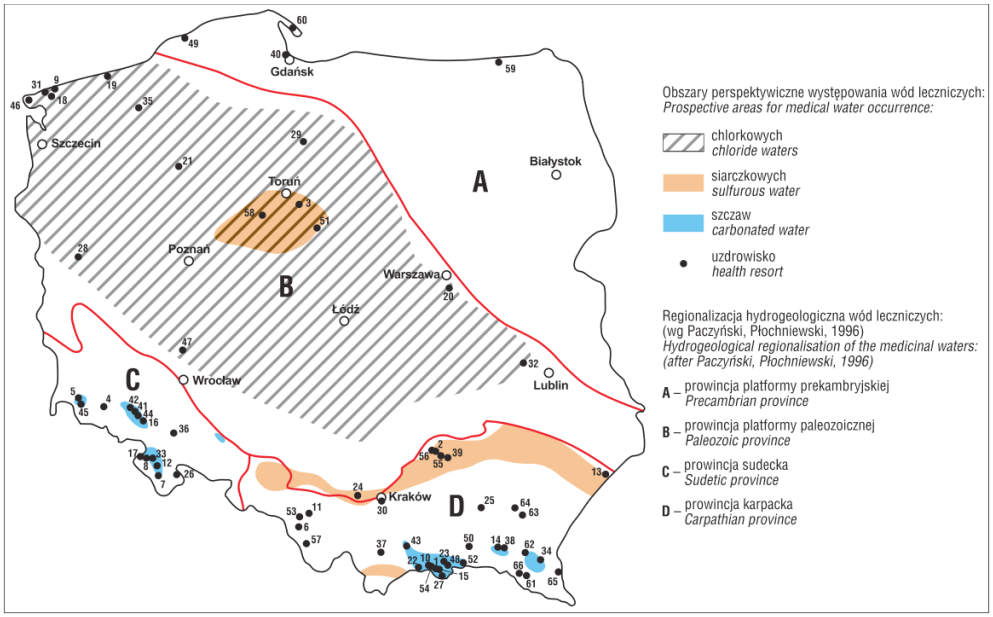

Fig. 2. Hydrogeological regionalization of medicinal water with marked points of health resorts (after Dowgiałło and Paczyński 2007)

Rys. 2. Regionalizacja hydrogeologiczna wód leczniczych z zaznaczonymi uzdrowiskami wód leczniczych

treated as a critical raw material. Access to drinking and industrial water resources is constantly deteriorating (mainly due to global warming) and it will become necessary to consider water as a critical resource. This criticality of water can be considered on a local, regional and global scale. However, it is impossible to protect all terrains with underground waters, but the question of how to better protect some mineral and medicinal waters still remains open.

Poland has a very long history and tradition of strong cultural and economic relations with amber (Szamałek 2016). According to archaeological data, the history of obtaining and processing Baltic amber dates back to the third millennium BC. The first reports of trade of Polish amber come from the period of the early Roman Empire, when the so-called "Amber Route" connected the Gulf of Gdańsk with Rome. The main Amber Route run from Aquileia on the Adriatic to the coast of the Gulf of Gdańsk. Within today's Polish borders, more than 750 locations (Figure 3) where Baltic amber was found or mined have been documented (Kowalska et al. 2018).

Fig. 3. Wet open-cast extraction of sand (primary commodity) and amber (associated commodity), "Przeróbka SL" deposit in Gdańsk. Phot. K. Twardowski, 2016 (Baltex Minerały) (taken from Kowalska et al. 2018)

Rys. 3. Podwodne wydobycie piasków (kopalina pierwotna) i bursztynu (kopalina towarzysząca), złoże „Przeróbka SL" w Gdańsku. Fot. K. Twardowski, 2016 (Baltex Minerały)

Gdańsk is considered to be the world capital of amber. The availability of amber resources determines the functioning of tens of thousands of people involved in the extraction and processing of amber, decorative and jewelry design and sales. Even today, amber is the best known and most popular jewelry stone in Poland, and the Polish amber industry is distinguishable by the unique character of its products (Kowalska et al. 2018). Amber plays an extremely important historical and social role in Poland. It is used mainly as a jewelry raw material. However, in Poland, it also has an ethnographic significance (it is an element of folk costumes of several historical lands in Poland), balneological (tinctures and medicinal pastes), as well as in the cosmetics industry.

Conclusions

The concept and scope of the term "mineral criticality" originated from and was developed in the United States. Gradually, the term has been applied in many countries, including within the European Union. The criticality of minerals mainly refers to the most important sectors of the economy, including in particular the military sector, information technology, new technologies and energy. The criticality of mineral resources was also introduced to Polish conditions in the area of mineral resources management. The term critical minerals is used alongside other terms such as scarce or strategic critical minerals. In Poland, there is a dynamic discussion on the unification and unambiguity of these terms. This discussion raises a number of arguments for adopting a particular terminology.

1. It is worth noting that the term "criticality" has different meanings in English and Polish. "Criticality" in English it means indispensability, importance and the role of a raw material for the economy. "Criticality" in Polish means a lack of acceptance, skepticism, and a lack of positive reference to a certain matter. The condition of the Polish economy and its role in the European and world economic system probably does not justify the introduction in Poland of the term "mineral criticality" in the meaning commonly accepted in economically developed countries of the world. Criticality of raw materials in Poland would be better explained as a special mixture of strategic and scarce raw materials.
2. Notwithstanding the comments and reservations raised in Section 2, attention should be drawn to the need to broaden the meaning of the term "mineral criticality." Criticality is also an attribute that determines the viability of a particular sector of economic life. This criticality may concern the conditions for maintaining the historical or cultural continuity of social life. In addition, there may be considerations of the preservation of public health, the existence of handicrafts and crafts. Therefore, the authors postulate to also extend the concept of mineral criticality to historical, cultural, social and health factors. Of course, the term "mineral criticality" will be used in different countries in a specific and individual way taking into account the conditions of socio-economic development of that particular country.
3. The criticality of different mineral raw materials also has an important economic aspect. The development of new mining projects concerning critical minerals can create jobs and increase local budgets through mining royalties or tributes to municipalities. Moreover, the criticality of raw materials has a promotional meaning. This contributes to the development of the country and the growth and strength of raw material exports, improving the balance of raw material trade.
4. Therefore, the concept of the criticality of minerals should be expanded to include raw materials necessary for:
   - conservation purposes of unique monuments (e.g. black limestone from Dębnik, called black marble);

- the jewelry sector in Poland using the unique Baltic amber,
- the sanatorium services sector (therapeutic raw materials – brines, peloids),
- the survival of biological life (drinking water).

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ON THE CRITICALITY OF MINERALS OTHERWISE. NEW APPROACH TAKING INTO ACCOUNT CULTURAL, SOCIAL AND HISTORICAL FACTORS

Keywords

mineral criticality, mineral resources policy, deficit minerals

Abstract

The importance and the role of minerals in the economy of a country or the world is highlighted by the use of the following terms: scarce mineral, critical mineral, and strategic mineral. The validity of the raw material in the economic processes and knowledge about the sources of its acquisition, access barriers, and the shaping of prices on the domestic and international market allow the development of an action strategy. The strategy must take into account the objective of the action, time horizon, the kind of the instruments that need to be used, and the scope of international cooperation. The importance of the raw material for the country is not only the volume of turnover and volume of production obtained thanks to its application. There are also historical, cultural and social reasons for its importance. The authors present arguments for another meaning of the term – mineral criticality. They also point out the linguistic differences between the term "criticality" in Polish and English. They propose to consider water, medicinal raw materials, some rock resources and amber as critical raw materials for various reasons.

O KRYTYCZNOŚCI SUROWCÓW MINERALNYCH INACZEJ. NOWE PODEJŚCIE ZE WZGLĘDU NA CZYNNIKI REGIONALNE, KULTUROWE, SPOŁECZNE I HISTORYCZNE

Słowa kluczowe

krytyczność surowców mineralnych, polityka surowcowa, surowce deficytowe

Streszczenie

Znaczenie i rola kopalin w gospodarce kraju lub świata przejawia się w stosowaniu różnych określeń: „kopalina deficytowa", „kopalina krytyczna", „kopalina strategiczna". Ważność surowca w procesach gospodarczych oraz wiedza o źródłach jego pozyskiwania, barierach dostępu, kształtowaniu się cen na rynku krajowym i zagranicznym pozwalają na opracowanie strategii działania państwa. Strategia musi uwzględniać cel działania, horyzont czasowy, rodzaj instrumentów koniecznych do wprowadzenia i stosowania oraz zakres współpracy międzynarodowej. Znaczenie surowca dla kraju wynika nie tylko z wielkości obrotów surowcem i wielkość produkcji uzyskanej dzięki jego wykorzystaniu. Określa to również jego znaczenie ze względów historycznych, kulturowych i społecznych. Autorzy przedstawiają argumenty przemawiające za innym znaczeniem terminu „krytyczność surowców mineralnych". Wskazują również na różnice językowe pomiędzy znaczeniem terminu „krytyczność" w języku polskim i angielskim. Proponują, aby za surowce krytyczne z różnych względów uznać wodę, surowce lecznicze, niektóre surowce skalne czy bursztyn.