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Niobium – a critical and conflict raw material of great economic significance – the state of the art

Introduction

Niobium (Nb) was isolated, described in 1801 by the English chemist Charles Hatchett, who gave it the name columbium. In 1949, the International Union of Pure and Applied Chemistry (IUPAC) officially adopted the name niobium. Industrial production began in the nineteen-thirties with the introduction of niobium and tantalum separation methods. The most important primary mineral sources of niobium are columbite (Fe, Mn)Nb_2O_6-(Fe, Mn) Ta_2O_6), minerals from the pyrochlore group, the tapiolite series, and others. In 1970, global production did not exceed nine tons of niobium concentrates, and after half a century, it reached the level about 100,000 tons (USGS 2022; TIC 2021, 2022).

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This sharp increase in the level of production in the late twentieth century was caused by the economic availability of niobium raw materials stimulated by the discovery of rich deposits in Brazil and Canada and the development of new technologies and applications generating increased demand. The leaders of global niobium production from the beginning of the wider industrial interest remain the same – Brazil (Alves and Coutinho 2015) and Canada. Since 1986, analysis of the niobium market and information on supply chain stability has been provided by the Tantalum-Niobium International Study Center (TIC). Manufacturers from the countries of the former Soviet Union and those countries that were under the political and economic protectorate of the USSR until 1990 did not join this organization. The use of niobium in the arms industry meant that data on mining production were not disclosed there. In current statistics, such as the United States Geological Survey (USGS), production volumes for Russia are also not available, although it is very likely that niobium production of the order of several hundred tons per year takes place there (Szlugaj and Smakowski 2015). Production of niobium concentrates is currently performed in about ten countries.

Niobium is a hard, ductile, steel-grey metal, resistant to corrosion and to most acids and bases. The economic importance of niobium is highly significant due to its use in the production of high-strength low-alloy steel, stainless steel for oil and gas pipelines, architec-

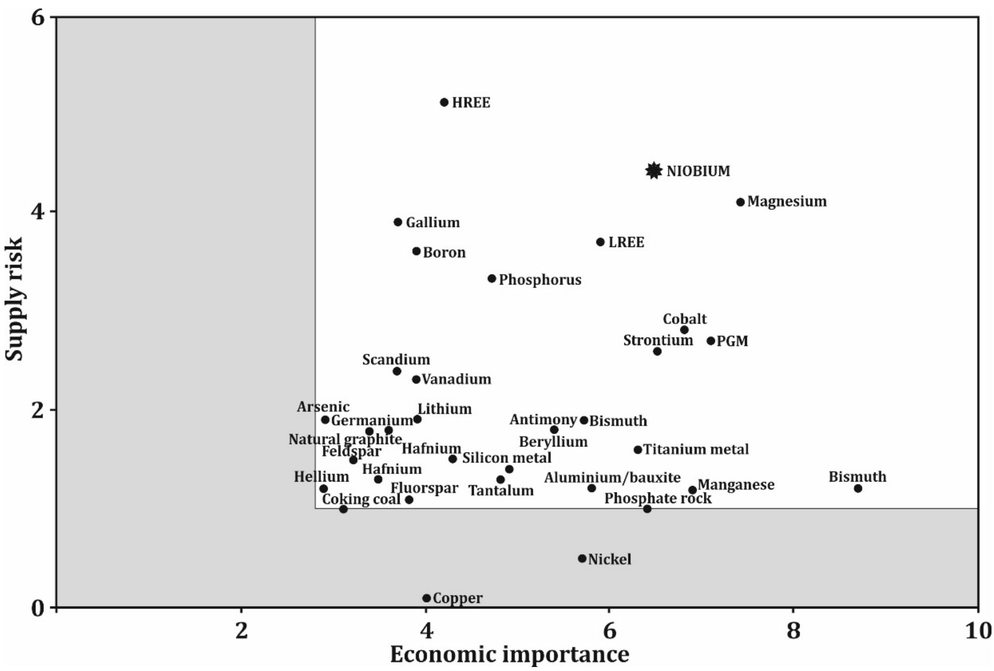

Fig. 1. Niobium on a background of critical raw materials for the EU economy (EC 2023)

Rys. 1. Niob na tle surowców krytycznych dla gospodarki UE tural applications, tool-grade steels, ship hulls, railroad tracks, trucks and cars (Pereira et al. 2022). Niobium and its compounds are used in the technologies of electronic and optical materials (e.g. ceramic capacitors, permanent magnets, screens, lenses) and chemical processing equipment (TIC). Niobium is an important raw material used in devices for the production of renewable energy (steel with the addition of niobium is used in the manufacture of windmill towers, their blades, photovoltaic cells, and in Li-Ion batteries) (Baldwin et al. 2015; Szlugaj and Radwanek-Bąk 2021). Due to its extremely high melting point, niobium is widely recognized as an excellent material for applications in space vehicle propulsion, particularly rocket engines and attitude controls. Ni, Ti, Co and Fe alloys with the addition of niobium are used in the manufacture of turbines for rocket engines, jet aircraft, and nuclear reactors. Recent reports indicate the possibility of using materials including niobium in electronic components (capacitors), electrical cells, solar cells, electric cars and related infrastructure, such as in charging stations (Sverdrup and Olafsdottir 2018; Golroudbary et al. 2019, McCaffrey et al. 2023).

In the assessment of the European Commission (EC 2023), niobium is classified as a critical raw material (Lundaev et al. 2023) of high economic importance among the listed raw materials and at the same time, involves a high risk of interruption in supply (Mohammed et al. 2023) (Figure 1).

1. Ore and deposit arrangement

Niobium is an element dispersed in the lithosphere; however, in relation to the tantalum co-occurring with it in the natural environment, it exceeds the latter by several times in frequency, which is a result of its lower atomic number. Niobium does not occur in a free state in the Earth's crust, and in an igneous environment, it has a high tendency to accumulate in rocks rich in alkalis. It is often part of the minerals containing tin, titanium, zirconium or tungsten. The share by weight of niobium in the Earth's crust, according to various authors, is estimated to be at from 8 to 20 ppm (Rudnick Sally 2003), and its Clarke number is understood to be at the level of 8 ppm (Rudnick Sally 2003; BGS 2011). In hypergene processes, niobium minerals, as with tin, tungsten or titanium minerals, are resistant to weathering. This may contribute to accumulation in the form of secondary placer deposits, which are sometimes of economic importance. Niobium is commonly found as an accessory component in igneous rocks, but deposit accumulations are rare. Niobium ores are usually of a complex nature, co-existing with Ta, Li, Sn and others (Krzak et al. 2021). Primary niobium deposits are associated with three main types of intrusive rocks (Figure 2, Table 1):

A. Carbonatites and associated alkali rocks.
B. Alkaline and peralkaline granites and syenites.
C. Granites and pegmatites with rare metals in association with lithium-caesium-tantalum (LCT).

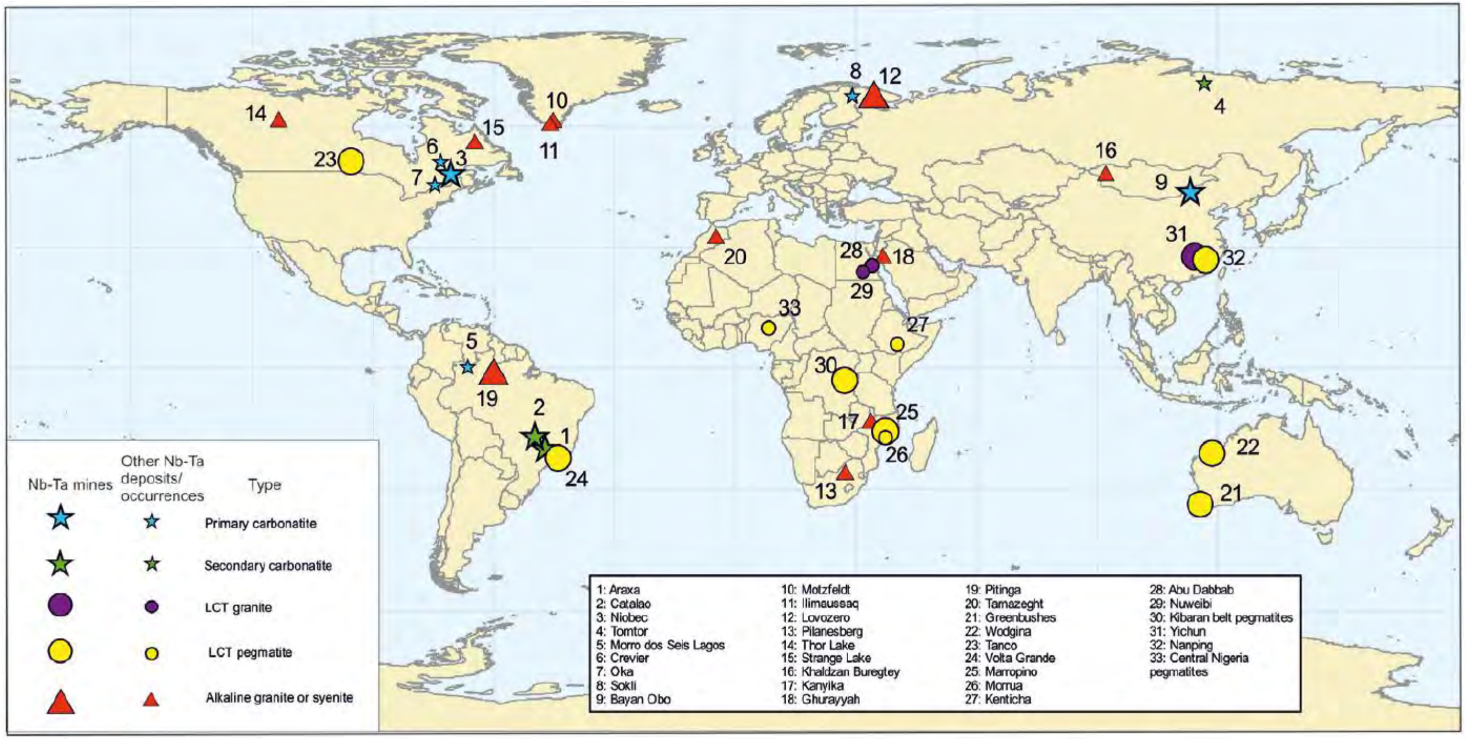

Fig. 2. Location of Nb-Ta mines and deposits (BGS 2011)

Rys. 2. Lokalizacja kopalń i złóż Nb-Ta

Table 1. Comparison of the most important types of Nb deposits

Tabela 1. Porównanie najważniejszych rodzajów złóż Nb

Deposits types	Basic parameters Ore resources (mln t): Nb_2O_5 content (%):
Primary carbonatites	10–100 0.40–0.65
Weathering carbonatites	up 1,000 up 3.0
Alkaline granites and syenites	up 100 0.1–1.0
Granite type LCT	up 100 up 0.05
Pegmatite type LCT	up 100 up 0.05

Source: BGS 2011.

A. Carbonatites are found almost exclusively in continental rift zones or rift valleys and consist of more than 50% of primary carbonate minerals. They generally take the form of steep plugs and dikes with a zonal structure, sometimes dome-shaped intrusions, and they accompany other alkaline rocks (mainly nepheline syenites, less often kimberlites, pyroxenites and peridotites). Carbonatites are typically rich in a number of elements, including rare earth elements (REE), barium, strontium, fluorine, phosphorus, niobium, zirconium, uranium, and thorium. Niobium mineralization of carbonatite is favored over tantalum, the content of which is usually low. Nb-bearing minerals include members of the perovskite and pyrochlore groups and silicates such as titanite. The niobium content of carbonatites is quite high, usually 0.01–0.1% (rarely approaching 1.0%), but these are generally not concentrations of economic importance. The largest deposits are found in Brazil (Araxa, Catalão, Morro dos Seis Lagos), with much smaller ones in Canada (Blue River, Crevier, Saint Honoré, Upper Fir, Oka), Australia (Mount Weld), and Russia (Tomtor). Individual occurrences have been documented in the Democratic Republic of Congo (Lueshe), and Sökli (Finland). The largest carbonatite deposit of rare earths at Bayan Obo (China) also shows high concentrations of Nb.
B. Deposits of alkaline granites and syenites (albitite) are usually associated with zones of rifts and sinkholes on platforms, beyond orogenic magmatic arcs. These can be independent small intrusions of alkaline rocks or those parts of large igneous massifs that exhibit significant alkalinity. These deposits show considerable variability of mineralization and thus content of useful components. Alkaline granites and syenites are a valuable source of iron, fluorine, niobium, zirconium, rubidium, uranium, thorium, and rare earths.

Examples of deposits are the Motzfeld and Ilimaussaq intrusive complexes (Greenland), Thor Lake-Nechalacho, Strange Lake (Canada), Lovozero (Russia), Kanyika (Malawi), Ghurayyah (Saudi Arabia), Pitinga (Brazil), Pilanesberg (South Africa), Yichun (China), Bikita (Zimbabwe), Abu Dabbab (Egypt) and Khaldzan-Buregtey (Mongolia).

C. Pegmatite deposits are associated with intrusions of rare-metal granites and pegmatites rich in lithium, caesium, and tantalum (LCT). They arise as the final stages of igneous and/or metamorphic processes due to the action of hydrothermal solutions, usually abundantly mineralised in tin. Most often, these are pegmatites with well crystallized cassiterite. They are accompanied by concentrations of the minerals niobium, tantalum, tungsten, lithium, beryl, and caesium. The main deposits are Greenbushes, Wodgina, and Bald Hill (Australia), Volta Grande and Mibra (Brazil), Kenticha (Ethiopia), Morrua and Marropino (Mozambique), Abu Dabbab and Nuweibi (Egypt), and Yichun (China).

A separate category of niobium placer deposits is sometimes distinguished. These deposits are typical for tropical countries (Central Africa, Australia, Brazil, Kazakhstan, and China). The outcrops of the primary rocks are usually covered with kaolinite-illite weathered clay rock with loose grains of tantalite, columbite, U-microlite, cassiterite, and scheelite. These deposits usually occur within 1 km of the original rock outcrop. Thus, the typical redeposition of useful components for placer deposits does not take place in this case or only takes place on a small scale.

Compared to deposits of other metals, most of the niobium deposits are not very large geological sites (Figure 3). Sites with resources from 1 to 10 million tons of Nb_2O_5 pre-

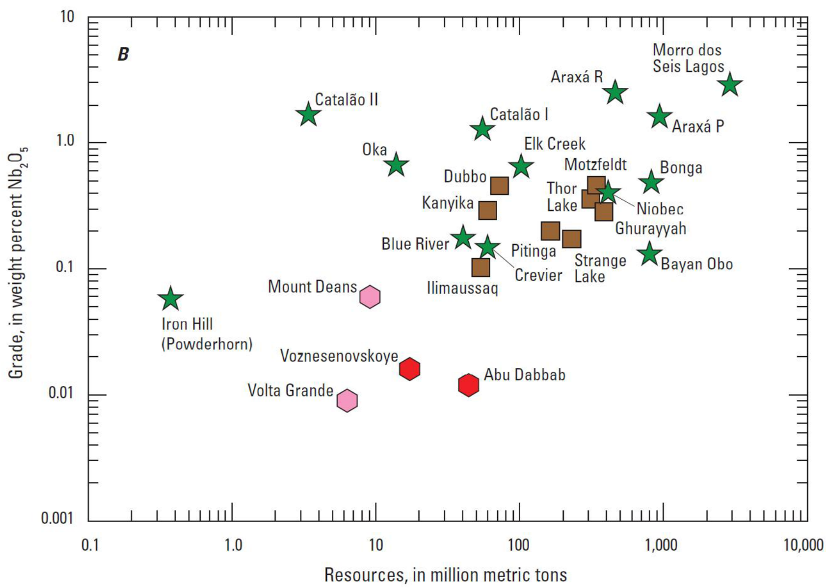

Fig. 3. Deposit resources and the Nb_2O_5 content in the ore (BGS 2011)

Rys. 3. Zasoby złóż i zawartość Nb_2O_5 w rudzie dominate. The total volume of ore resources is usually several hundred million tons of ore and more with a relatively low metal content by weight. Most deposits are in the range of 0.1–1.0% Nb_2O_5.

2. Methodology

Characteristic of commodity trade flow requires a proper statistical approach and numerical data analysis, including e.g. volume of production, consumption, imports, prices, etc. Unfortunately, in the case of niobium, this data is generally scattered and difficult to obtain. Long-term and systematically collected statements (although sometimes selective) are available in the Tantalum-Niobium International Study Center (TIC) and the United States Geological Survey databases institutions on an ongoing basis monitoring the global situation. A detailed analysis of the available data and statistics required a careful query of irregularly published, sometimes laconic press reports. Numerous source publications, company reports, availability and feasibility studies of the of mining projects, referring to the geological occurrence of economically useful concentrations of niobium in mineral deposits, communications and reports on current and new industrial applications, as well as announcements and publications characterizing market fluctuations in the trade of niobium raw materials were reviewed. The obtained data was verified in relation to TIC and USGS reports considered as credible, building a comprehensive view of the niobium raw material economy and presenting the main determinants of its market. Collected and aggregated by the authors' quantitative statistics made it possible to judge the current market situation by indicating a high degree of supply monopolization and the risk of delivery. In addition, a discussion was undertaken and the conclusions were formulated in the context of the environmental constraints of primary niobium mineral acquisition and the social conditions of mining exploitation.

3. Results

3.1. The necessity of economic development and the safeguarding of mineral resources

The study of the niobium market requires characterization with regard to four distinct categories:

A. The geography of primary sources (deposits).

B. The types of raw materials.

C. The types and industries of end-user applications.

D. The prices of basic raw materials.

A. A key feature of the niobium market is the high concentration of supply, limited practically to three producers: Companhia Brasileira de Metallurgia e Mineração (CBMM), the CMOC Group Limited (formerly China Molybdenum Co. Ltd.) and Niobec, part of Magris Performance Materials. Such a large degree of concentration means that the niobium market can be seen as an oligopolistic market. These producers have a combined share of 97–98% of the world supply of niobium raw materials (Roskill, mordorintelligence.com). The first two companies operate in Brazil, with CBMM (owner of the Araxa deposit), owning 78% of the market shares, firmly dominating the others and recognized as a world leader in production, sales, and pricing. The market supremacy of CBMM, backed by Chinese (15% stake) and Japanese-Korean (15% stake) capital, is expected to continue as the group actively increases and declares further production capacity increases in the coming years. CBMM headquartered in Brazil and with offices in China, the Netherlands, Singapore, Switzerland and the United States, supplies niobium raw materials to approximately fifty countries for over 400 commercial customers. China's CMOC group is the world's second-largest niobium producer, with a 12% market share. After reforms in its ownership structure, the company is a private holding company with state capital and operates in the Boa Vista and Morro De Padre deposits in the region of Catalão (Brazil). Completing the triad of niobium producers is the Canadian Niobec company, which manages the deposit of the same name and holds 7–8% of the market share. In addition to the concentration of niobium production in Brazil and Canada, marginal amounts of the global supply come from African countries such as the Democratic Republic of the Congo, Nigeria, Rwanda, Ethiopia, Burundi and Uganda, as well as from Russia (Figure 4, Table 2).

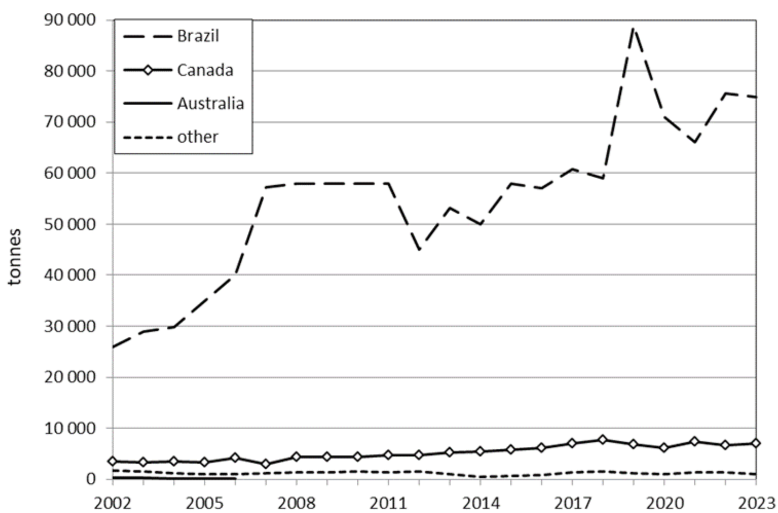

Fig. 4. World niobium mine production (based on USGS data)

Rys. 4. Światowa produkcja górnicza niobu

Table 2. Niobium mine production in the years 2000–2023

Tabela 2. Produkcja górnicza niobu w latach 2000–2023

	2000	2010	2015	2020	2023^{e}		Proportion 2023/2000 (%)
					quantity (t)	share (%)	
Brasil	30,000	44,300	58,852	59,819	75,000	90.01	250
Canada	2,290	4,420	5,600	6,400	7,000	8.40	305
Australia	160	–	–	–	–	–	–
Burundi	6	13	10	30	–	–	–
Ethiopia	7	22	15	7	–	–	–
Mozambique	5	4	3	9	–	–	–
Nigeria	35	23	53	50	–	–	–
Rwanda	176	120	244	156	190	0.23	107
Congo (Kinshasa)	110	130	454	560	540	0.65	490
Uganda	–	–	0	7	–	–	–
Russia	700	700	439	431	440	0.53	62
Other					150	0.18	–
World	33,489	49,732	64,320	67,469	83,320	100	249

Source: USGS 2001, 2011, 2016, 2021, 2024; Szlugaj and Smakowski 2015.

In 2022, the Brazilian government launched a program to enhance its national niobium production capacity in an attempt to diversify a mining sector which so far has been based almost exclusively on iron ore (www.bnamericas.com). The program is intended to support the development of production technologies throughout the niobium raw material production chain, as well as to enable further geological exploration in order to increase the resource base. By contrast, the two most advanced exploration and production projects currently relate to the Kanyika Niobium Project in Malawi (feasibility study), envisaging the extraction of 3,250 tons of niobium and 140 tons of tantalum (Globe Metals and Mining 2021). The main shareholder, Globe Metals and Mining, is close to signing an agreement with the government of Malawi to build a mine and begin mining operations. The second project is the Elk Creek Project in the USA (technical feasibility study) performed under the auspices of NioCorp. According to the report (NioCorp 2022b), it is expected that, in addition to the production of raw materials of scandium and titanium, almost 7,500 tons of ferroniobium will be produced per year. The St-Georges Eco-Mining Corp RÉAL reports on the promising outlook of the Notre Dame Project in Québec (Canada), in the context of increasing the resource base of niobium and rare earth minerals (www.juniorminingnetwork.com). It is also worth mentioning the British Circular Niobium project (www.iom3.org), overseen by Beta Technology in collaboration with Echion Technologies and the British Geological Survey (BGS), to develop a business model for niobium recycling technologies.

B. The commercially traded forms of niobium are products of ore processing in the form of concentrates of pyrochlore, concentrates of columbite (also called niobite), members of the columbite-tantalite family, and the more highly processed ferroniobium, nickel niobium, niobium oxides, metallic niobium or powders and alloys of niobium produced via vacuum metallurgy. Columbite concentrates in international trade normally contain a minimum of 50% Nb_2O_5, while up to 50% of the share may also be comprised of tantalum oxides. The latter should constitute a share of not less than 5%. Thus, the paid amount of metal includes the total content of Nb_2O_5 + Ta_2O_5, without distinction of additional payment for the Ta_2O_5 content. Both pyrochlore and columbite often contain slightly elevated levels of naturally occurring thorium and uranium, usually high enough to be classified as radioactive products in both their use and transportation. It is the responsibility of the manufacturer or the dealer to monitor the radioactivity and, if necessary, to purify the concentrates of these impurities. In general, ferroniobium supplied to the European market contains 63–67% Nb_2O_5, not exceeding the specified standards of carbon, silicon, aluminum, sulfur and phosphorus content, and is supplied in lump form. More highly purified and more specialized niobium raw materials command higher prices. The reference level is the price quote for niobium pentoxide with a purity of 99.5 or 99.99% most often in the incoterms formulas EXW, FOB, CIF China.

C. The market for applications of niobium includes the broadly understood steel sector (high-strength, stainless, special use, construction, etc.), the production of superalloys, superconducting magnets, capacitors, batteries, glass, etc., while in terms of end users, the construction, automotive and transport, aviation, defense, oil and gas sectors, etc. can be distinguished (Figure 5).

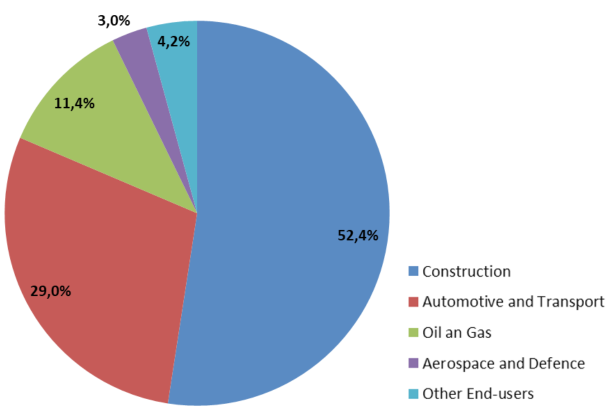

Fig. 5. Structure of niobium raw materials end use by industry (NioCorp 2022a, mordorintelligence.com)

Rys. 5. Struktura końcowego wykorzystania surowców niobu według przemysłu

The use of niobium in its dominant form as ferroniobium is the main determining factor in the global market. According to estimates, almost 90% of the global supply of niobium in this form of raw material is allocated to the steel industry. In addition to the mass consumption of niobium in the steel industry, this metal is used in the production of superalloys, carbides, superconductors, electronic components, functional ceramics, and biocomponents. These latter fields of application are surpassed in value by the quantitative consumption of the steel industry, and the range of applications is enormous. Superalloys of niobium (based on iron, nickel, cobalt, and zirconium) are used as fuel element jackets and pressure pipes in nuclear reactors; they form the structural material of gas and wind turbines (towers), engine components and coatings of spacecraft and aircraft; they are components of turbochargers, heat-resistant and combustion equipment, while niobium carbide is used to produce ultra-durable tools and refractory coatings of nuclear reactors, and in medicine, niobium compounds are used for medical imaging and for components of bone implants.

In recent years, extensive research has been performed on the use of niobium and its compounds in batteries. The focus has been on the construction of new types of cathodes based on niobium oxides as well as on the use of niobium alloys with various metals as anode materials, e.g. Nb-Ti oxide (NTO); these alloys have a larger capacity and improve the cyclic performance of the battery. Composite materials containing niobium oxides have been tested as separators to prevent short circuits in batteries and as a high-performance anode material in lithium-ion batteries; it has been shown that niobium used as a coating of electrodes prevents the degradation of their surface and protects against the formation of lithium dendrites (McCaffrey et al. 2023, niobium.tech).

Toshiba's pioneering use of niobium-titanium oxides (NTO) in batteries has demonstrated its extraordinary utility while maintaining excellent properties (i.e. long service life and charging speed) for widely used lithium-titanium (LTO) anodes. NTO has about three times the theoretical capacity density of LTO and enables the production of high-performance and ultra-safe, ultra-fast batteries for electric vehicles (mordorintelligence.com, Toshiba – PRNewswire, CBMM|Niobium press release).

D. The price volatility of niobium raw materials is generally low in relation to other metallic raw materials, which is undoubtedly one of the key factors for the durability and reliability of the supply chain as well as for the apparent stability of this market. Despite the relative stability and minor price volatility in the last decade, it is worth noting that since the beginning of the twenty-first century, with the growth of industrial interest in this metal, a significant bull market has been observed expressed in current prices, both for less processed ferroniobium and for a steady upward trend in niobium oxides (Figure 6).

The trend in niobium prices depends on supply-and-demand relationships and is not significantly influenced by speculative activity. Shortages or surpluses of primary raw materials are key factors in market pressure, while supply from secondary sources of around 20% is a minor factor. An example of this is the fact that the sharp rebound in

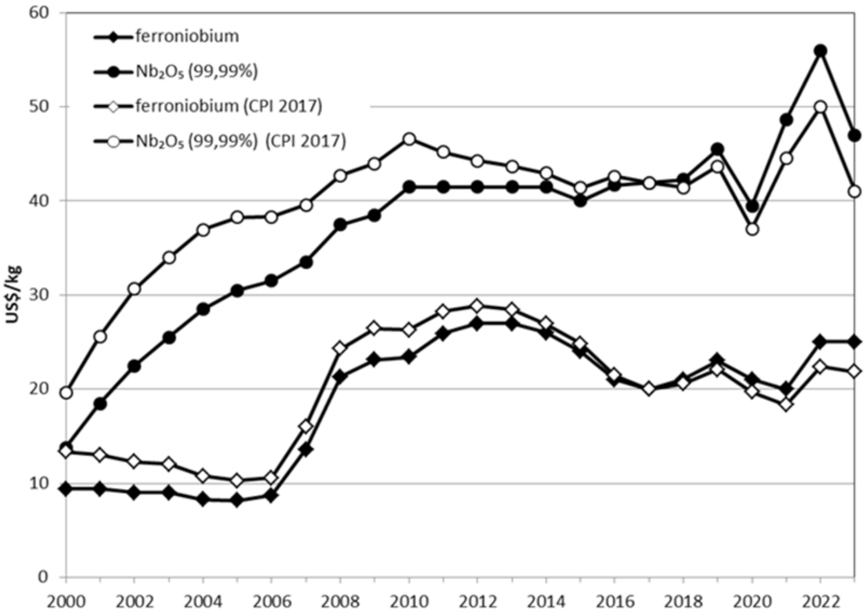

Fig. 6. Evolution of niobium raw material prices (ferroniobium prices – weighted average prices of niobium in US imports and exports, oxide prices – average EXW and FOB China 99.99% Nb_2O_5 prices)

Rys. 6. Ewolucja cen surowca niobu (ceny żelazoroniobu – średnie ważone ceny niobu w imporcie i eksporcie USA, ceny tlenków – średnie ceny EXW i FOB China 99,99% Nb_2O_5)

ferroniobium prices in 2006 after a wave of slight declines was due to the increasing demand for niobium alloy additives for HSLA steels (Mackay and Simandl 2014). Given the high degree of market monopolisation, unforeseen production restrictions in Brazil may pose a threat to price stability. A negative impact, not only on niobium prices and the market, was exerted by the COVID-19 pandemic, when many investments and construction projects were halted (Kekec et al. 2022; Paz-Barzola et al. 2023). Price declines were then observed which have returned to an upward trend quite quickly as a result of the current revival of trade relations and the recovery in the construction industry. The increasing consumption of the largest users of niobium raw materials, China and Japan, is also undoubtedly a strong component of price growth and the stabilization of the entire niobium market.

3.2. The management of niobium raw materials in Poland

There are no niobium mineral deposits in Poland; therefore, niobium raw materials or niobium commodities are not produced and the entire domestic demand is covered by imports.

The most important niobium commodity imported to Poland is ferroniobium. Variable level of deliveries, not exceeding 700 tpy, mainly from Brazil, Canada, the Netherlands and France, have been reported in the years from 2012 to 2021 (Szlugaj and Smakowski 2015; Galos and Lewicka, eds. 2022). In these years, re-exports were recorded, which did not exceed 93 tpy, to Spain, the Netherlands, Germany, Ukraine, Czech Republic and Slovakia (Galos and Lewicka, eds. 2022).

Domestic demand for raw niobium, niobium powders, and niobium products is met entirely by imports, which in the period 2012–2016 was quiet stable, ranging from 9 to 54 kgpy (Galos and Lewicka, eds. 2022). In the years 2017–2021, there was a sharp increase in the import of these niobium raw materials, which in the record year of 2018 reached 25,752 kg, and then in the years 2019–2021, it dropped to almost 15,600 kg (Galos and Lewicka, eds. 2022). Although this trade is reported under a common item with rhenium, niobium goods are the majority of this volume. Until 2020, the majority has been delivered from China, the US, Germany, Belgium and the Netherlands. In 2021, the main supplier was Brazil, and China took second place. Until 2011, small and irregular re-exports were reported (Szlugaj and Smakowski 2015). Since 2011, all the reported exports have consisted of rhenium, the production of which has started in KGHM Polska Miedź SA (Galos and Lewicka, eds. 2022).

Niobium in Poland is consumed almost exclusively as ferroniobium by the steel industry for the production of stainless and heat-resisting steels, and other high-grade special steels. In the years 2012–2021, consumption did not exceed 606 tons, and the amount of consumption corresponds to the condition of the domestic steel industry (Galos and Lewicka, eds. 2022).

4. Environmental hazards caused by niobium mining

Dynamic growth in the production of niobium raw materials in response to the market demand is largely covered by Brazil (about 88% of the market share) and Canada (about 11% market share). The increased demand for niobium has resulted in the exploration of new deposits in Brazil, including the Seis Lagos deposit complex. However, the development of deposits is inevitably connected with possible harmful effects of entering the virgin Amazon regions which raises justified protests. Haste and the desire for profit may mean deforestation and loss of unique biodiversity (Siqueira-Gay and Sánchez 2020). However, the largest suppliers do not always keep up with the current demand. Mining in Australia ceased in 2006. These relatively small shortages were exploited by smaller suppliers, mainly African countries, such as Nigeria, Rwanda and the Democratic Republic of Congo (DRC). In the period 2008–2012, the largest producer of niobium concentrates in Africa was Rwanda, occasionally outpaced by the DRC. It should be noted that numerous mines in Africa (Ethiopia the Kenticha Mine, Nigeria, Mozambique Noventa Ltd.) were and continue to be assessed as risky in terms of supply due to outdated methods of exploitation and the unstable political situation. Exploitation in these countries is often performed by small operators, without licenses or regulated status, as artisanal and small-scale mining (ASM). The total production from African countries, Russia and China accounts for only 2% of the world's primary supply and in Africa, this supply comes almost exclusively from artisanal and small-scale activities. There are areas where production is controlled by local militant groups who exploit the local population for slave labor (Kelly 2014). In the countries of Central Africa, it still pays to run a robber economy, often using terror against workers, although signs of change can be seen, for example, in the activities of the Ministry of Natural Resources of Rwanda, where since 2016, the monitoring of mines and the supervision of the origin of primary raw materials of columbite has been implemented. Similar measures have been implemented in the DRC for several years (Diemel 2018). Despite the changes, countries centered on the African Great Lakes region are still considered risky trading partners.

Apart from social problems, mines in Central Africa do not use any or use almost no technologies to reduce their negative impact on the environment. A threat is posed by both active mines and post-exploitation facilities. The main factors are deforestation and the levelling of terrain, the storage of unprotected and uninsulated waste, the discharge of process water into watercourses, and the lack of reclamation and monitoring of pollution (Muhire et al. 2021). Antiquated mining in Africa with virtually no pro-environmental procedures (EIA, impact monitoring, remediation) is a serious burden on the local and regional biodiversity, the landscape, and other environmental resources (Butsic et al. 2015; Attuquayefio et al. 2017; DERA 2018). The pollution of soil, water and air causes harmful effects on humans. It is estimated that the production of 1 ton of coltan concentrate (a mixture of columbite and tantalum) amounts to 1,000 tons of waste (ARM 2018). Wastes often contain Sn, Ta but also U, and Th (Carvalho et al. 2021). These elements are easily washed away and enter the soil and surface water. The contamination of water and soil with radioactive minerals may endanger the health of nearby residents in the future.

The lack of modern processing technologies means that the final product of these projects is the above-entioned coltan concentrate. This product, undivided into its component parts, is the subject of trade relations, but the content of niobium in the concentration is omitted in the quotation price for the transaction. Between 2010 and 2014, 95% of tantalum supplies to the European Union came from Africa and it can be assumed that together with the tantalum, niobium was also supplied, which was then extracted in Europe as a by-product. The supply of niobium from this source is virtually undetectable, although such niobium content may represent a fairly significant supply stream. EUROSTAT statistics on the volume of the supply of Nb and Ta concentrates to the European Union for the last decades are classified and given in generalizations together with vanadium and zirconium, which makes it impossible to trace the actual scale of supply. However, it seems that for many years, EU countries have been profiting from these transactions by importing coltan concentrates from Central African countries. In 2021, the EU adopted a law banning imports of ores and niobium concentrates from conflict-affected and high-risk areas (EU 2021). It cannot be clearly indicated that this prohibition covers tantalum concentrate while not covering the accompanying Nb, although it must be assumed that niobium is subject to similar restrictions as the main component metal. It is also worth mentioning that tantalum, along with tin, tungsten and gold, is classified as one of the so-called 3TG conflict mineral. The effects of EU regulations aimed at ensuring a sustainable supply in terms of origin of more than 95% of total imports into the EU of tin, tantalum, tungsten and gold raw materials are reflected in the prices of these raw materials, especially since detailed due diligence from importers is required, which may not necessarily translate into the prices of niobium.

5. Discussion

The wide possibilities of using niobium in key areas of the economy, such as defense, transport, aviation and astronautics, mean that the raw materials of this metal are recognized by many countries and organizations (the USA, the UK, Russia and the European Union) as strategic raw materials. The lack of effective and readily available substitutes further highlights the crucial position of this metal. In terms of tonnage, the niobium market is a small market. In the last decade, with annual market-feeding mining production ranging from 50,000 to 97,000 tons (Table 2), the total amount of metal traded was slightly more than 120,000 tons, although analysts believe this market will grow cumulatively at a rapid rate of around 5% by 2026 (Industry-arc.com, Roskill). The most important feature of the niobium market is the very large number of consumers and the limited, small number of suppliers. On the demand side, China, India, and Japan lead the way, with the remaining consumer countries Australia, USA, Canada, Mexico, Germany, Great Britain, Italy, France, Russia, Brazil, Argentina, Saudi Arabia, and South Africa also deserve a mention. The main suppliers of raw materials of niobium (mainly in the form of concentrates but also in the form of ferroniobium) are Brazil and Canada, with only 1–2% coming from other sources.

Niobium consumption in the decade 2010–2019 grew by almost 5% on an annual basis (CAGR), with the largest acceleration observed since 2016. One of the main drivers of the growth of raw material consumption was the restructuring of the Chinese steel industry and the introduction of new technical standards in the construction industry there. It is obvious that the construction industry, the largest consumer of niobium in the world, driven by the growing urban population, rapid urbanization, projects and investments reinvigorated after the pandemic crisis in China, North America, Australia, and the emerging economies of Asia (India) and also the commercial and extravagant showcase projects in the Middle East, is undoubtedly the strongest and best predictor for the entire niobium market. In addition, the effective displacement of vanadium as an alloying additive by niobium has increased supply pressure. The already high prices of ferrovanadium (hitherto the main alloy component) roughly doubled in 2018 and forced the search for substitutes. Imports of niobium to China increased by 30% year-on-year in both 2018 and 2019. Niobium has been of interest to the Chinese industry for years, which is why as many as thirteen Chinese companies that deal with the processing of concentrates (for comparison there are three Brazilian and one Australian) are affiliated in the T.I.C. (T.I.C. Members; accessed in March 2024). Despite the decline in the prices of vanadium raw materials, a return to their use is currently not an obvious outcome, since the much lower volatility and higher predictability of niobium raw material prices provide greater comfort for consumers. The largest supplier of niobium raw materials, the Brazilian CBMM, is actively promoting the use of niobium in the steel industry, although according to Roskill analysts (2021), steel production in China, for example, is approaching the peak of its production capacity. Non-steel applications account for only a small percentage of the total consumption and no doubt in the foreseeable future, the steel industry will continue to be the largest market for niobium; however, batteries for electric vehicles, power cells for smartphones, computers and other NTO-based consumer electronics as well as nanocrystalline applications are expected to grow at double-digit rates in the next decade, depending on global technological developments.

Despite the introduction of some rudimentary elements of the management of coltan mining in Africa, violence and terror are still observed, sometimes disingenuously called protection (Geenen 2012). The high investment risk means that only small private companies from Canada, Australia and the UK and China are present in Central Africa (Strzelecki et al. 2021). Because coltan is primarily a source of tantalum, its African origin is the subject of international statistics. Between 2010 and 2014, 95% of tantalum purchased by EU countries came from Africa.

A virtually undetectable supply of niobium is probably provided along with these tantalum concentrates. In international transactions, concentrates containing a minimum of 30% Ta_2O_5 are traded, and this metal content is the basis for quotation prices, and any admixtures of accompanying Nb_2O_5 are generally ignored. Despite their low content, niobium additives can represent a fairly significant supply stream, technologically possible to obtain. EUROSTAT statistics on the volume of supply of Nb and Ta concentrates to the European Union for the last decades are classified and given as a generalization together with vanadium and zirconium. Aggregated coverage makes it impossible to trace the actual scale of supply.

If we assume that tantalum concentrates with 30% Ta_2O_5 content may contain up to 15% Nb_2O_5, then assuming that in 2020, 50% of the world tantalum production (i.e. 850 t) came from African countries, it would correspond (based on the ratio of Ta and Nb content in concentrates) to the supply stream of 425 t of metallic niobium. Presumably, this value is strongly overestimated (based on the assumption of about 15% of the Nb_2O_5 admixture in the concentrate); however, in the context of mining conditions in Africa, this corresponds to the largest producer, Nigeria. Assuming that the transaction was made based solely on the content of Ta_2O_5 in the concentration, the presence of niobium in the concentrate would be a significant bonus. Tantalum, as is commonly known, along with tin, tungsten, and gold, is classified as a so-called 3TG conflict mineral. On 1 January 2021, the European Union enacted and introduced new legal obligations towards the uppliers of these metals (EU – the Conflict Minerals Regulation; Elbel et al. 2023). Niobium, accompanying tantalum in concentrates, is subject to the same analogous restrictions as the main component metal in coltan. The effects of EU regulations aimed at ensuring a sustainable supply in terms of the origin of more than 95% of the total imports into the EU of tin, tantalum, tungsten and gold raw materials are reflected in the prices of these raw materials, especially since detailed due diligence from importers is required.

Conclusions

The dominant position of a few producers (Brazil and Canada) and the producer-dictated price applicable in settlements make the market stable and relatively predictable. The wide applications of niobium in steel products and possible applications in the rapidly developing electromobility technologies seem to provide safe, sustainable, and profitable mining investment returns in this field of activity. The previously mentioned prospect of the wider use of niobium raw materials in modern battery cells is an important factor in the development of smaller producers.

Advanced-stage mining projects in Malawi and the United States in the terms of the launching of mining operations will allow supply sources to be slightly diversified and will at least partially ameliorate the monopoly of Canada (the stable market position of Brazil is rather undisputed). It will also be an important step to initiate the recycling of niobium. Secondary sources can be an effective buffer with regard to price fluctuations.

Russia's war with Ukraine (Lewicka et al. 2022), as well as the preceding Covid-19 pandemic (Gałaś et al. 2021) caused serious perturbations in the supply chain of many commodity groups. Some supply shortages in the niobium market should be foreseen in the short term. National entities which are manufacturers of missiles and jet aircraft will try to secure access to raw materials used in military technologies, including niobium. It seems that this situation will favor not only the established suppliers but will also favor the escalation of coltan mining by small, semi-legal or even terrorist organizations in Central Africa. Furthermore, it must be mentioned that African countries, despite attempts to obtain technological support, do not have sufficient means to improve this state of affairs. The uncertainty of mining investments and the possibility of concluding profitable transactions (e.g. the purchase of a concentrate based on the content of tantalum while drawing additional profit from niobium production) creates conditions for maintaining the operation of technologically antiquated mines and for exploiting the local population.

Since the beginning of the twenty-first century, the niobium market has undergone dynamic growth in the production, consumption and prices of its raw materials. According to market analysts, this growing trend is expected to continue.

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REFERENCES

Alves, A.R. and Coutinho, A.D.R. 2015. The Evolution of the Niobium Production in Brazil. *Materials Research* 18(1), pp. 106–112, DOI: 10.1590/1516-1439.276414.

ARM 2018. The Economic Contributions of Artisanal and Small-Scale Mining in Rwanda: Tin, Tantalum, and Tungsten. *Alliance for Responsible Mining*. 79 pp.

Attuquayefio et al. 2017 – Attuquayefio, D.K., Owusu, E.H. and Ofori, B.Y. 2017. Impact of mining and forest regeneration on small mammal biodiversity in the Western Region of Ghana. *Environ Monit Assess* 189, DOI: 10.1007/s10661-017-5960-0.

Baldwin et al. 2015 – Baldwin, S., Bindewald, G., Brown, A., Chen, C., Cheung, K., Clark, C., Cresko, J., Crozat, M., Daniels, J., Edmonds, J., Friley, P., Greenblatt, J., Haq, Z., Honey, K., Huerta, M., Ivanic, Z., Joost, W., Kaushiva, A., Kelly, H., King, D., Kinney, A., Kuperberg, M., Larzelere, A., Liddell, H., Lindenberg, S., Martin, M., McMillan, C., Melchert, E., Mengers, J., Miller, E, Miller, J., Muntean, G., Phelan, P., Russomanno, C., Sabouni, R., Satsangi, A., Schwartz, A., Shenoy, D., Simon, A.J., Singh, G., Taylor, E., Ward, J. and Williams, B. 2015. *Quadriennal Technology Outlook*. US Department of Energy. [On-line:] http://energy.gov/quadrennial-technology-review.

BGS 2011. Mineral profil, Niobum-Tantalum. British Geological Survey, London.

BGS 2015. Risk List 2015. An Update to the Risk Index for Elements or Element Groups that Are of Economic Value, London.

Bradley et al. 2017 – Bradley, D.C., McCauley, A.D. and Stillings, L.M. 2017. *Mineral-deposit model for Lithium-Cesium-Tantalum pegmatites. Scientific Investigations Report 2010-5070-0*. USGS, Reston, Virginia: 48.

Butsic et al. 2015 – Butsic, V., Baumann, M., Shortland, A., Walker, S. and Kuemmerle, T. 2015. Conservation and conflict in the Democratic Republic of Congo: The impacts of warfare, mining, and protected areas on deforestation. *Biological Conservation* 191, pp. 266–273, DOI: 10.1016/j.biocon.2015.06.037.

Carvalho et al. 2021 – Carvalho, F.P., Tufa, M.B., Oliveira, J.M. and Malta, M. 2021. Radionuclides and radiation exposure in tantalite mining, Ethiopia. *Archives of Environmental Contamination and Toxicology* 81(2), pp. 648–659, DOI: 10.1007/s00244-021-00858-8.

DERA 2018. Rohstoffrisikobewertung – Niob. Deutsche Rohstoffagentur, Berlin.

Diemel, J.A. 2018. Authority and access to the cassiterite and coltan trade in Bukama Territory (DRC). *The Extractive Industries and Society* 5(1), pp. 56–65, DOI: 10.1016/j.exis.2017.12.001.

EC 2017. *Niobium*. [In:] *Study on the review of the list of Critical Raw Materials*. Executive summary. European Commission Brussels: pp. 470–485.

EC 2023. *Study on the Critical Raw Materials for the EU. Final Report*. European Commission, Brussels.

Elbel et al. 2023 – Elbel, J., Bose O'Reilly, S. and Hrzic, R., 2023. A European Union corporate due diligence act for whom? Considerations about the impact of a European Union due diligence act on artisanal and small-scale cobalt miners in the Democratic Republic of Congo? *Resources Policy* 71, DOI: 10.1016/j.resourpol.2022.103241.

Gałaś et al. 2021 – Gałaś, A., Kot-Niewiadomska, A., Czerw, H., Simić, V., Tost, M., Wårell, L. and Gałaś, S. 2021. Impact of Covid-19 on the Mining Sector and Raw Materials Security in Selected European Countries. *Resources* 10, DOI: 10.3390/resources10050039.

Geenen, S. 2012. A dangerous bet: The challenges of formalizing artisanal mining in the Democratic Republic of Congo. *Resources Policy* 37(3), pp. 322–330, DOI: 10.1016/j.resourpol.2012.02.004.

Globe Metals and Mining, 2021. *Kanyika niobium project. Project feasibility and economics.* Midvale, Australia, 122 pp.

Golroudbary et al. 2019 – Golroudbary, S.R., Krekhovetckii, N., Wali, M. and Kraslawski, A. 2019. Environmental Sustainability of Niobium Recycling: The Case of the Automotive Industry. *Recycling* 4(1), DOI: 10.3390/recycling4010005.

Galos, K. and Lewicka, E. eds. 2022. *Mineral storage management in Poland in 2012–2022* (*Gospodarka surowcami mineralnymi w Polsce w latach 2012–2022*), Kraków: MERRI PAS, 383 pp. (*in Polish*).

Kekec et al. 2022 – Kekec, B., Bilim, N. and Ghiloufi, D. 2022. An insight on the impact of COVID-19 on the global and Turkish mining industry. IOS Press, *Work* 72(1), pp. 1163–1174, DOI: 10.3233/WOR-220037.

Kelly, J., 2014. "This mine has become our farmland": Critical perspectives on the coevolution of artisanal mining and conflict in the Democratic Republic of the Congo. *Resources Policy*. 40, 100–108.

Krzak et al. 2021 – Krzak, M., Gałaś, A. and Król, K. 2021. Tantalum market at the beginning of the 21 stcentury (*Rynek tantalu na początku XXI wieku*). *Przegląd Geologiczny* 69(4), pp. 234–243, DOI: 10.7306/2021.13 (*in Polish*).

Lewicka et al. 2022 – Lewicka, E., Burkowicz, A., Czerw, H., Figarska-Warchoł, B., Galos, K., Gałaś, A., Guzik, K., Kamyk, J., Kot-Niewiadomska, A. and Szlugaj, J. 2022. The Russian-Ukrainian war versus the mineral security of Poland. *Gospodarka Surowcami Mineralnymi – Mineral Resources Management* 38(3), pp. 5–30, DOI: 10.24425/gsm.2022.142792.

Lundaev et al. 2023 – Lundaev, V., Solomon, A.A., Le, T., Lohrmann, A. and Breyer, C. 2023. Review of critical materials for the energy transition, an analysis of global resources and production databases and the state of material circularity. *Minerals Engineering* 203, DOI: 10.1016/j.mineng.2023.108282.

Mackay, D.A.R. and Simandl, G.J. 2014. Geology, market and supply chain of niobium and tantalum – a review. *Miner Deposita* 49(8), pp. 1025–1047, DOI: 10.1007/s00126-014-0551-2.

McCaffrey et al. 2023 – McCaffrey, D.M, Nassar, N.T., Jowitt, S.M. and Padilla, A.J. 2023. Embedded critical material flow: The case of niobium, the United States, and China. *Resources, Conservation and Recycling* 188, DOI: 10.1016/j.resconrec.2022.106698.

Melcher et al. 2008 – Melcher, F., Graupner, T., Henjes-Kunst, F. Oberthür, T., Sitnikova, M., Gäbler, E., Gerdes, A., Brätz, H., Davis, D. and Dewaele, S. 2008. *Analytical Fingerprint of Columbite-Tantalite (Coltan). Mineralisation in Pegmatites – Focus on Africa*. Ninth International Congress for Applied Mineralogy 8–10 September 2008, Brisbane.

Mohammed et al. 2023 – Mohammed, K.S., Khalfaoui, R., Doğan, B., Sharma G.D. and Mentel, U. 2023. The reaction of the metal and gold resource planning in the post-COVID-19 era and Russia-Ukrainian conflict: Role of fossil fuel markets for portfolio hedging strategies. *Resources Policy* 1(1), DOI: 10.1016/j.resourpol.2023.103654.

Muhire et al. 2021 – Muhire, I., Manirakiza, V., Nsanganwimana, F., Nyiratuza, M., Inzirayineza, T.A. and Uworwabayeho, A. 2021. The environmental impacts of mining on Gishwati Protected Reserve in Rwanda. *Environmental Monitoring and Assessment* 193(9), DOI: 10.1007/s10661-021-09372-9.

niobium.tech [On-line:] https://niobium.tech/en [Accessed: 2023-03-14].

NioCorp 2022a. Critical minerals for U.S. supply chain security.

NioCorp 2022b. NI 43-101 technical report feasibility study, Elk Creek project, Nebraska. Denver, USA, 659 pp.

Paz-Barzola et al. 2023 – Paz-Barzola, D., Elizalde-Pardo, D., Romero-Crespo, P., Escobar-Segovia, K., Jiménez--Oyola, S. and Garcés-León, D. 2023. The impact of COVID-19 for the Ecuadorian mining industry in 2020:risks and opportunities. *Mineral Economics* 36(3), pp. 1–9, DOI: 10.1007/s13563-023-00369-z.

Pereira et al. 2022 – Pereira, P. H.N., Cury, C.M, de Campos, A.A., Malpass, G.R.P. and Alves, E.R. 2022. Production of niobium: overview of processes from the mine to products. *Journal of Mining and Metallurgy* 58A(1), pp. 1–20, DOI: 10.5937/JMMA2201001H.

Regulation (EU) 2017/821 of the European Parliament and of the Council of 17 May 2017 laying down supply chain due diligence obligations for Union importers of tin, tantalum and tungsten, their ores, and gold originating from conflict-affected and high-risk areas.

Rudnick, R.L. and Sally, G. 2003. Composition of the continental crust. *Treatise Geochem* 3, pp. 1–64, DOI: 10.1016/B0-08-043751-6/03016-4.

Schulz et al. 2017 – Schulz, K.J., Piatak, N.M. and Papp, J.F. 2017. *Niobum and Tantalum*. [In:] Schulz, K.J., DeYoung, J.H. Jr, Seal, II R.R. and Bradley D.C. (ed.), *Critical Mineral Resources of the United States–Economic and Environmental Geology and Prospects for Future Supply.* USGS, Reston: Chapter M.

Siqueira-Gay, J. and Sánchez, L.E. 2020. Keep the Amazon niobium in the ground. *Environmental Science & Policy* 111, DOI: 10.1016/j.envsci.2020.05.012.

Simandl et al. 2018 – Simandl, G.J., Burt, R.O., Trueman, D.L. and Paradis, S. 2018. Economic Geology Models 2, Tantalum and Niobium: Deposits, Resources, Exploration Methods and Market – A Primer for Geoscientists, Geosciences Canada, 45, pp. 85–96.

Strzelecki et al. 2021 – Strzelecki, R., Wołkowicz, S., Elenga, H. and Kounkou, G.R. 2021. In search of critical raw materials for Poland: Republic of the Congo – Geology, mineral resources potential, concession conditions (*W poszukiwaniu surowców krytycznych dla Polski. Republika Konga – geologia, potencjał surowcowy, warunki koncesyjne*). *Przegląd Geologiczny* 69(6), pp. 339–355 (*in Polish*).

Sverdrup, H.U. and Olafsdottir, A.H. 2018. A System Dynamics Model Assessment of the Supply of Niobium and Tantalum Using the WORLD6 Model. *BioPhysical Economics and Resource Quality* 3(2), DOI: 10.1007/s41247-018-0038-3.

Szlugaj, J. and Radwanek-Bąk, B. 2021. Lithium sources and their current use. *Gospodarka Surowcami Mineralnymi – Mineral Resources Management* 38(1), pp. 61–88, DOI: 10.24425/gsm.2022.140613.

Szlugaj J. and Smakowski T. 2015. *Niob*. [In:] Smakowski, T., Galos, K. and Lewicka, E. (eds), *Bilans Gospodarki Surowcami Mineralnymi Polski i Świata*. Warszawa: PIG-PIB, pp. 955–960 (*in Polish*).

T.I.C. 2018. Bulletin No. 172, 174.Tantalum-Niobium International Study Center, Brussels.

T.I.C. 2019. Bulletin No. 176. Tantalum-Niobium International Study Center, Brussels.

T.I.C. 2020. Bulletin No. 181. Tantalum-Niobium International Study Center, Brussels.

T.I.C. 2021. Bulletin No. 184. Tantalum-Niobium International Study Center, Brussels.

T.I.C. 2022. Bulletin No. 188. Tantalum-Niobium International Study Center, Brussels.

USGS 2001. Cunningham, L.D. 2001 – *Niobium*. [In:] *USGS Mineral Commodity Summaries*. USGS Publ., Washington, pp. 50–51.

USGS 2011. Papp, J.F. 2011 – *Niobium*. [In:] *USGS Mineral Commodity Summaries*. USGS Publ., Washington, pp. 110–111.

USGS 2016. Papp, J.F. 2016 – *Niobium*. [In:] *USGS Mineral Commodity Summaries*. USGS Publ., Washington, pp. 116–117.

USGS 2021. Callagham, R.M. 2021 – *Niobium*. [In:] *USGS Mineral Commodity Summaries*. USGS Publ., Washington, pp. 114–115.

USGS 2024. Friedline, C.A. 2024 – *Niobium*. [In:] *USGS Mineral Commodity Summaries*. USGS Publ., Washington, pp. 127–128.

NIOBIUM – A CRITICAL AND CONFLICT RAW MATERIAL OF GREAT ECONOMIC SIGNIFICANCE – THE STATE OF THE ART

Keywords

mineral deposits, niobium market, conflict mineral, resource security

Abstract

The economic importance, global market, primary resources and secondary sources of niobium are discussed in this paper. Niobium concentrate is the first commercial product of the enrichment process; however, the overwhelming majority of the niobium concentrate supply is processed into ferroniobium, which dominates international trade. In this form, niobium raw materials are used in the steel industry as an alloying agent (alloy additive). The production of \oxides and other compounds of niobium, such as carbides, alloys and metallic niobium are currently of much less commercial significance. The addition of a very small amount of niobium, of the order of 0.01%, changes the properties of steel fundamentally, increasing its strength, resistance to atmospheric factors or high temperatures, etc. The addition of niobium in other products also changes their properties, e.g. permanent magnets become superconductors. As a result, niobium is currently widely used around the world as a compo-

nent of sustainable technologies, which has a large positive impact on the environment by reducing the energy and material consumption of the manufacturing processes. The increase in the spectrum of niobium applications in advanced technologies, considered to be the technologies of the future, means that the widely recognized critical importance of niobium continues to grow. It can be assumed that the war between Ukraine and Russia will cause significant disturbances in the global metals market, including that for niobium.

NIOB – KRYTYCZNY I KONFLIKTOWY SUROWIEC O DUŻYM EKONOMICZNYM ZNACZENIU – STAN WIEDZY

Słowa kluczowe

złoża kopalin, rynek niobu, minerały konfliktowe, bezpieczeństwo surowcowe

Streszczenie

W artykule omówiono znaczenie gospodarcze, rynek światowy, surowce pierwotne i wtórne niobu. Koncentrat niobu jest pierwszym komercyjnym produktem procesu wzbogacania, jednak zdecydowana większość dostaw koncentratów niobu jest przetwarzana na żelazoniob, który dominuje w handlu międzynarodowym. W tej postaci niob jest stosowany w przemyśle stalowym jako dodatek stopowy. Produkcja tlenków i innych związków niobu, takich jak węgliki, stopy i niob metaliczny ma obecnie dużo mniejsze znaczenie komercyjne. Dodanie bardzo małej ilości niobu, rzędu 0,01%, zmienia zasadniczo właściwości stali, zwiększając jej wytrzymałość, odporność na czynniki atmosferyczne, wysokie temperatury itp. Obecność niobu w innych produktach zmienia także ich właściwości, m.in. magnesy trwałe stają się nadprzewodnikami. Dzięki temu niob jest obecnie szeroko stosowany na całym świecie jako składnik zrównoważonych technologii, który ma duży, pozytywny wpływ na środowisko, zmniejszając energochłonność i materiałochłonność procesów produkcyjnych. Zwiększenie spektrum zastosowań niobu w zaawansowanych technologiach, uznawanych za technologie przyszłości, powoduje, że powszechnie uznawany jest za surowiec krytyczny. Można przypuszczać, że wojna między Ukrainą a Rosją spowoduje istotne zaburzenia na światowym rynku metali, w tym niobu.