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Janina WISZNIEWSKA

# Mineral resources of the Suwałki region*

This paper presents the resources of the most significant mineral deposits of the Suwałki region, NE Poland (Fig. 1). The deposits are described in a stratigraphic sequence, from the oldest Precambrian ones in the crystalline basement, to the youngest ones in the Quaternary formations. Ilmenite-magnetite ores from the region of Krzemianka, Udryn, Jeleniewo, and Jezioro Okrągłe in the Suwałki Massif are presented, as well as veiny ilmenite-sulphide nelsonites from the vicinity of Łopuchowo. Next, the occurrences of elements, mainly TR-bearing ones, from the Ełk and Tajno Massifs are discussed. Water resources and different kinds of sands and gravels from Quaternary deposits of the Suwałki region complete this presentation.

## INTRODUCTION

The region of Suwałki is rich in deposits of mineral resources. Many of them have been exploited continuously, e.g., water resources (surface and groundwaters) and rock resources. There are also untouched raw materials hidden deep in the ground making up the treasure of this land. The deposits of metals such as Fe, Ti, V, Cu, Ni, Co, Cr and REE, occur mainly in the crystalline basement and are related to the magmatic activity of the Precambrian.

Within Palaeozoic and Quaternary sequences, horizons of mineralized waters occur. Their resources and flows are variable, yet interesting as deposits. Rock deposits including natural boulders, gravels, clay ceramic raw materials, quartz sands, lacustrine chalk and gyttja belong to the Quaternary formation.

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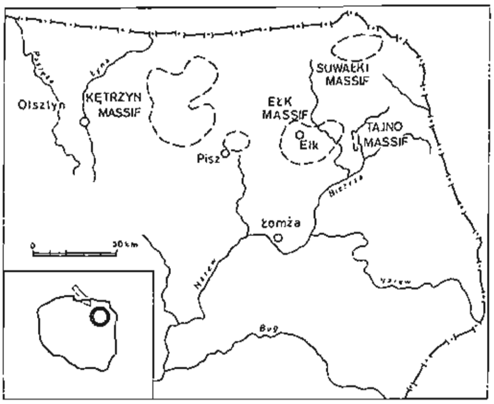



Fig. 1. Sketch map of the region (NE Poland)
Szkic sytuacyjny omawianego regionu (NE Polska)

## PRECAMBRIAN DEPOSITS OF METAL ORES

The most spectacular deposits of the Suwałki region, which have provided controversy for years, are the ores of the iron-titanium-vanadium formation occurring within the anorthosite-norite Suwałki Massif (Fig. 2). They were found in small positive magnetic anomalies of Krzemianka, Udryn, Jeleniewo and Jezioro Okrągłe below 850 m (i.e., top of the crystalline basement) down to 2300 m J. Znosko (1962) — Fig. 3.

Magnetite ores are related to the Gothian activity stage of the sub-platform Mazurian complex chiefly built of Rapakivi-like granitoids and anorthosite massifs associated with them. The ores form lenses, nests, schlieren, veins and irregular bodies from several to over 100–200 m thick. The boundaries of the ores with the adjacent rocks are variable: sharp, rugged or wavy with anorthosites, straightline or gradually alternating with norites.

The ore consists of a mineral aggregate containing titanium and vanadium-bearing magnetite, ilmenite and hematite-ilmenite occurring in different ratios from 1:1 to 5:1 and even 10:1. Magnetite contains numerous products of disintegration of solid solutions such as: ulvöspinel, ilmenite, and aluminum spinels. There are the following accessory minerals: iron sulphides — pyrrhotite, pyrite, marcasite; copper sulphides — chalcopyrite, cubanite, chalcocite; and nickel and cobalt sulphides — pentlandite, bravoite, millerite, linneite, violarite and others. They make up 1–3% of the ores (S. Kubicki, J. Siemiątkowski, 1979; S. Speczik *et al.*, 1988; A. Kozłowska, J. Wiszniewska, 1991). The iron content depending on the quality of ores ranges from 20 to 50% wt. The average chemical composition of the ores is as follows: 27% Fe, 7% $TiO_2$ and 0.3% $V_2O_5$.

The Krzemianka anomaly is located in the western part of the Suwałki Massif, close to its metamorphic cover (Fig. 3). The ore zone is arched, 1.5 km wide and 4–5 km long. The maximum south to north elongation of ore bodies reaches almost 1100 m and their width is 320 m. The ore series in Krzemianka is sometimes up to 750 m thick (Fig. 4). The deposit has been explored with over 70 boreholes of overall length 135,521 m. The ore resources documented by Warsaw Geological Enterprise are 726 mln t in the A+B+$C_1$ categories, and 350.6 mln t in the $C_2$ category (altogether 1076.6 mln t of economic ores) and 475.2 mln t of subeconomic ore (A. Parecki *et al.*, 1989; S. Przeniosło *et al.*, 1993). Most Krzemianka ores occur at a depth interval of 1100–1700 m.

The Udryn deposit is located at the central part of the Suwałki intrusion, about 4 km east of the Krzemianka deposit. The area of the Udryn anomaly covers 4 km$^2$. Up to 1983, 12 boreholes were drilled in this region down to 2300 m. The overall area of the Udryn deposit is 773,000 m$^2$. Ilmenite-magnetite rocks containing over 15% Fe were reckoned as ores. The deposit dips 45°SW. The length of ore bodies forming lenses and veins reaches 3 km and their width is up to 0.6 km (Fig. 5). The Udryn deposit resources estimated by the Polish Geological Institute are 263.5 mln t of economic ores of 20% Fe content and 131.3 mln t of subeconomic ores of 15.0–19.9% Fe content (M. Subieta *et al.*, 1985).

The deposits do not exhibit any significant differences in mineral composition, yet the Krzemianka ores are richer in parts containing spinel, whereas very little spinel occurs in Udryn. In addition, the rocks from the Udryn region are more faulted, resulting in division of the deposit into several blocks.

Similar mineralization has been found within the Jeleniewo and the Jezioro Okrągłe anomalies but very few boreholes have been drilled there.

At the Jeleniewo deposit, ores were encountered in the depth interval 1115–2300 m. Over the ore series rest leucogabbronorites, and below are anorthosites. Ore bodies form lenses parallel to each other and elongated NW–SE, dipping SW. Ferrolites build 7–8% of the whole volume of the core. Inferred resources are estimated at about 116 mln t.

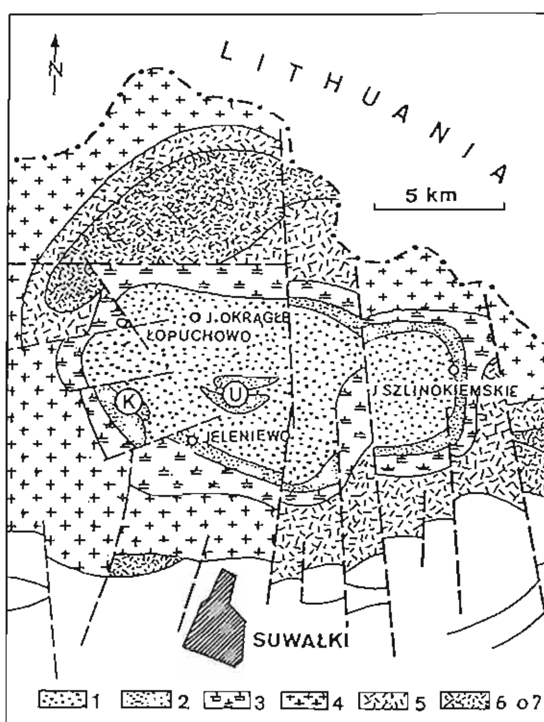



Fig. 2. Geological map of the Suwałki intrusion (after S. Kubicki and W. Ryka, 1982, modified)
K — Krzemianka deposit, U — Udryn deposit, 1 — anorthosites, 2 — norites, 3 — gabbronorites and diorites, 4 — granitoids, 5 — granitogneisses, 6 — gneisses, 7 — boreholes

Mapa geologiczna intruzji suwalskiej (według S. Kubickiego i W. Ryki, 1982, zmodyfikowana)
K — złoże Krzemianka, U — złoże Udryn, 1 — anortozyty, 2 — noryty, 3 — gabronoryty i dioryty, 4 — granitoidy, 5 — granitogneisy, 6 — gnejsy, 7 — otwory wiertnicze

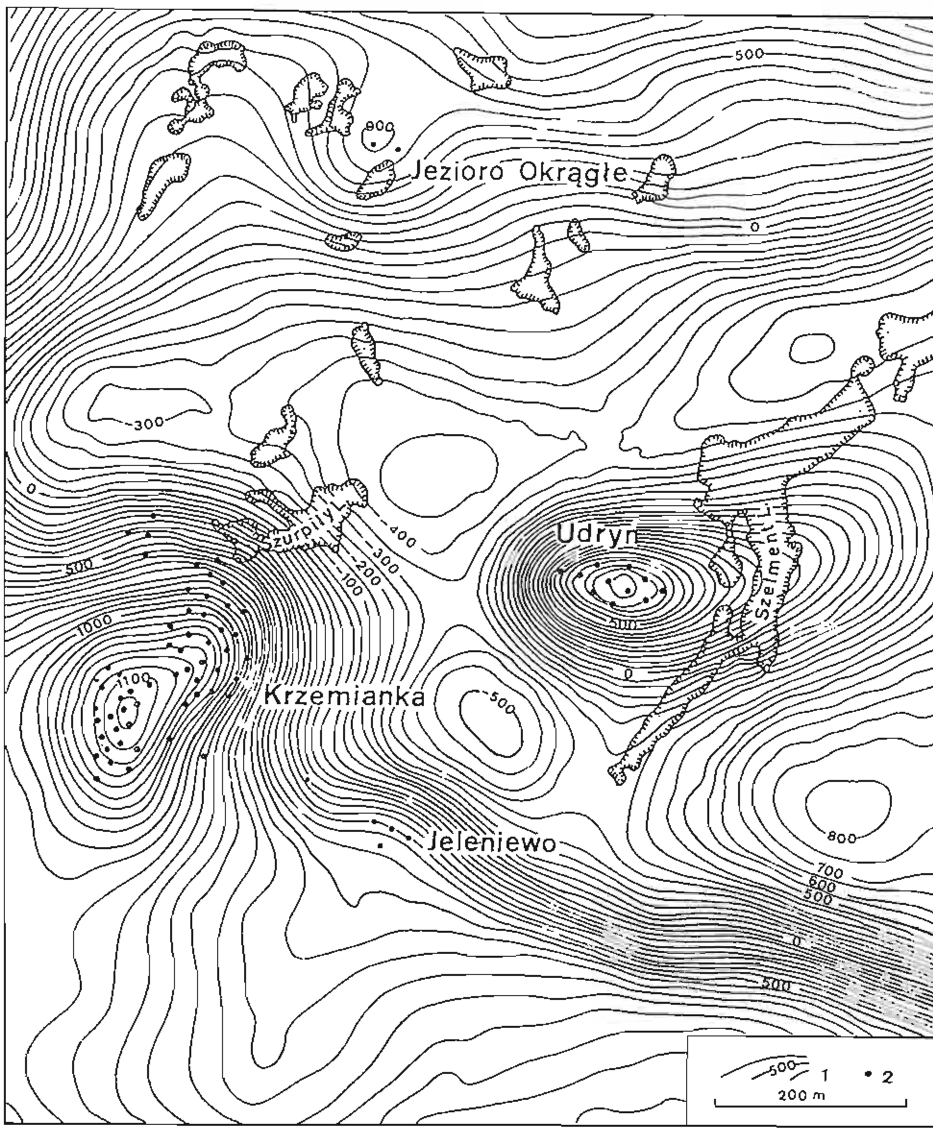



Fig. 3. Map of magnetic anomalies of the Suwałki Massif
1 — magnetic isolines, 2 — boreholes
Mapa anomalii magnetycznych masywu suwalskiego
1 — izolinie magnetyczne, 2 — otwory wiertnicze

The Jezioro Okrągłe anomaly is located in the NW part of the Suwałki intrusion. The ores from this region form lenses, streaks and irregular bodies up to 20 m thick. Anorthosites, anorthosites with magnetite and ilmenite schlieren as well as ferrolites were found in the

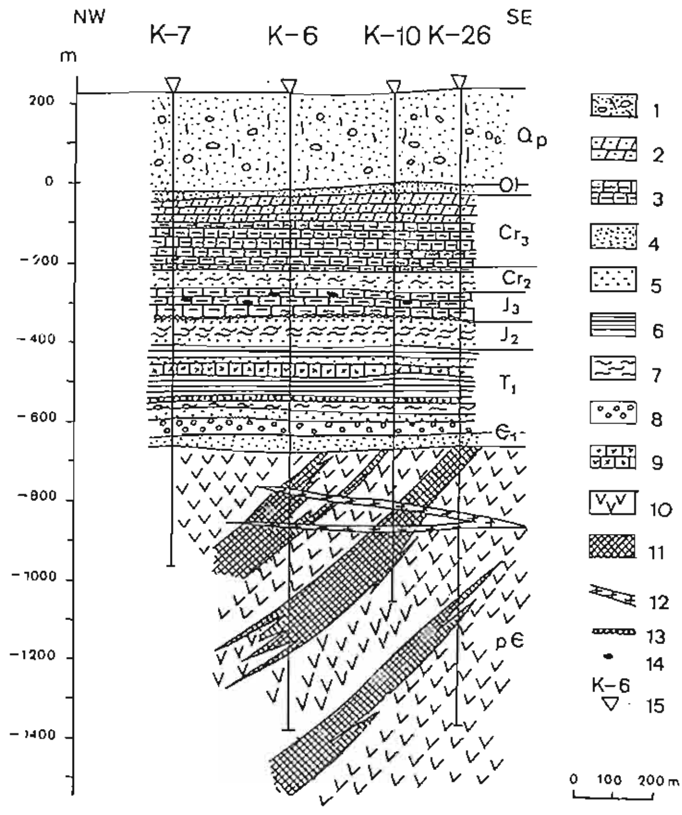


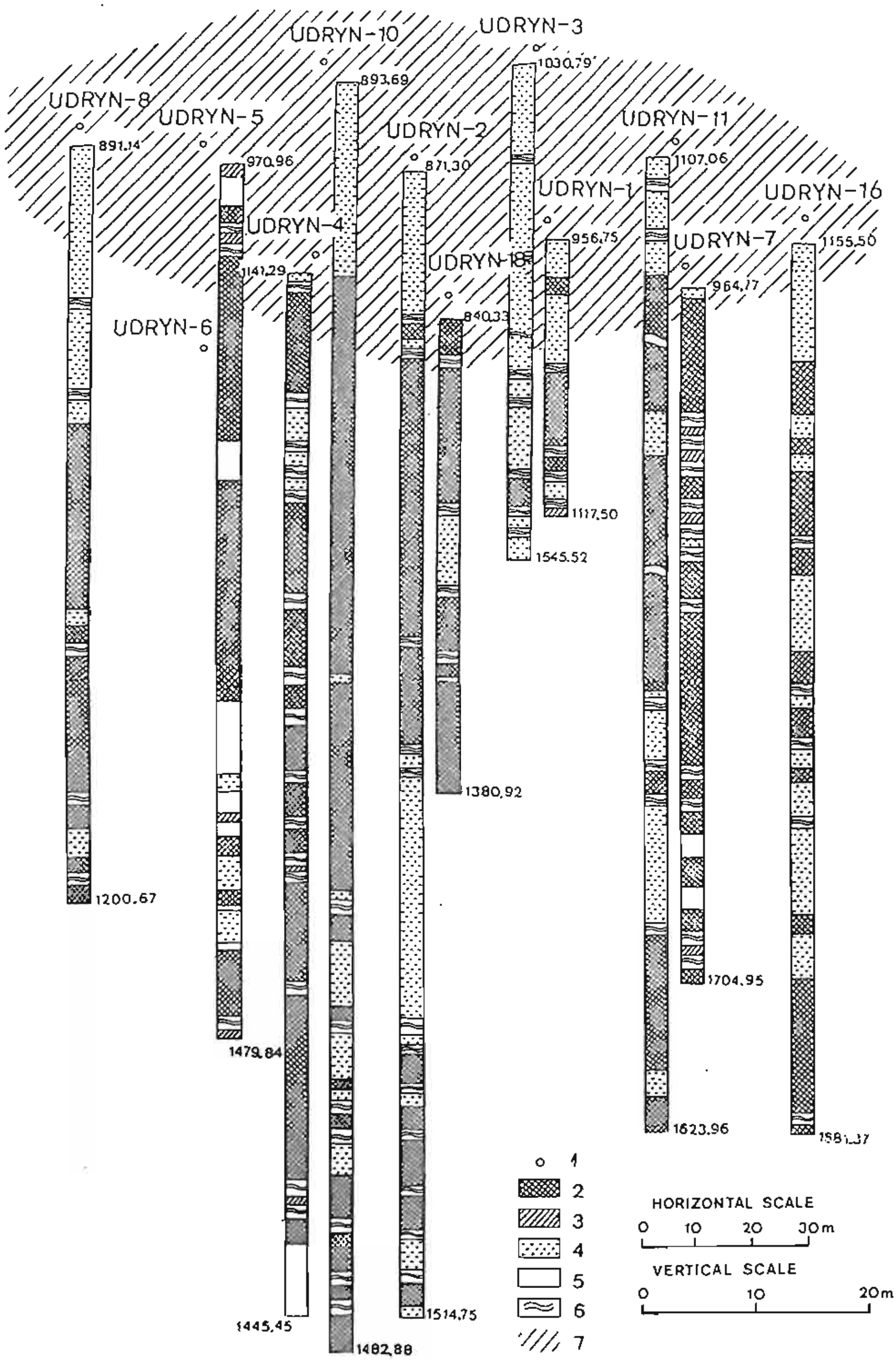

Fig. 4. Geological cross-section of the Krzemianka deposit (after J. Znosko, 1962, modified *fide* J. B. Tomaszewski, J. Ostrowski, 1989)

1 — Pleistocene sediments, 2 — gaizes, 3 — marls, 4 — sands, 5 — sandstones, 6 — clayey shales, 7 — mudstones, 8 — arcoses, 9 — oolite limestones, 10 — barren anorthosites and norites, 11 — ore-bearing norites and anorthosites, 12 — granitoide veins, 13 — nodular bed, 14 — cherts, 15 — boreholes; Qp — Pleistocene, Ol — Oligocene, $Cr_3$ — Upper Cretaceous, $Cr_2$ — Middle Cretaceous, $J_3$ — Upper Jurassic, $J_2$ — Middle Jurassic, $T_1$ — Lower Triassic, $Є_1$—Lower Cambrian, pЄ — Precambrian

Przekrój geologiczny przez złoże Krzemianka (według J. Znoski, 1962, zmodyfikowany *fide* J. B. Tomaszewski, J. Ostrowski, 1989)

1 — utwory plejstocenu, 2 — gezy, 3 — margle, 4 — piaski, 5 — piaskowce, 6 — łupki ilaste, 7 — mułowce, 8 — arkozy, 9 — wapienie oolitowe, 10 — noryty i anortozyty płonne, 11 — noryty i anortozyty rudne, 12 — żyły granitoidowe, 13 — warstwa bułasta, 14 — krzemienie, 15 — otwory wiertnicze; Qp — plejstocen, Ol — oligocen, $Cr_3$ — kreda górna, $Cr_2$ — kreda środkowa, $J_3$ — jura górna, $J_2$ — jura środkowa, $T_1$ — trias dolny, $Є_1$ — kambr dolny, pЄ — prekambr

borehole profiles. The mineralization builds 3% of the core volume and is of an injective character. Extreme chromium content in ferrolites reaches 3400 ppm (J. Wiszniewska *et al.*, 1989; K. Nejbert, J. Wiszniewska, 1994).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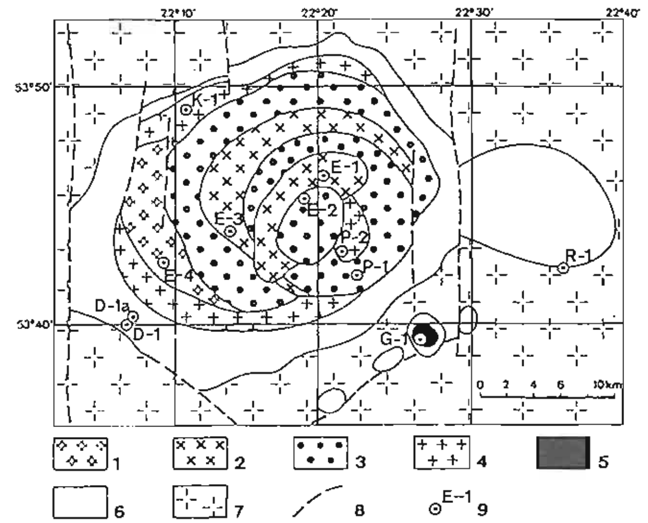


Fig. 6. Map of the Ełk syenite massif at the level of –750 m (after W. Ryka, 1994)
1 — microperthitic syenites, 2 — foid syenites, foidolites, 3 — foid-bearing syenites, 4 — quartz syenites and porphyries, 5 — quartz diorites — microperthitic-quartz syenites, 6 — fenites, 7 —Precambrian Mazovian complex, 8 — faults, 9 — boreholes

Mapa syenitowego masywu ełckiego na poziomie –750 m (według W. Ryki, 1994)
1 — syenity mikropertytowe, 2 — syenity foidowe i foidolity, 3 — syenity foidonośne, 4 — syenity kwarcowe i porfiry, 5 — dioryty kwarcowe — syenity kwarcowo-mikropertytowe, 6 — fenity, 7 — prekambryjski kompleks mazowiecki, 8 — uskoki, 9 — otwory wiertnicze

It is assumed that the ores of the Suwałki Massif have a magmatic origin, yet the problem of their deposition is more complex and closely related to the genesis of anorthosites and accompanying rocks.

The Suwałki ores examined are a source of iron, titanium and valuable and demanded vanadium. They also contain Ni, Co and Cu which occur as sulphides associated with the ores.

In the Łopuchowo IG 1 borehole situated at the western, marginal zone of the Suwałki Massif, below the diorite and monzodiorite complex, veiny, ore-bearing apatite rocks, not found previously, were encountered. Their thickness is from a dozen to several tens of centimetres. Their main minerals are: chloro-fluorapatite, magnetite, ilmenite, iron, cobalt, nickel and copper sulphides as well as biotite, chlorite, orthite and others. The rocks in

Fig. 5. Diagrams of borehole profiles of the deposit at the Udryn ore field (after J. Wiszniewska, 1993)
1 — borehole, 2 — economic ore (Fec > 20%), 3 — subeconomic ore (Fec > 20%), 4 — subeconomie ore (Fec = 15–19.9%), 5 — non-ore rock, 6 — break in profile, 7— area of documented deposit

Zestawienie profili wierniczych serii złożowej w polu rudnym Udryn (według J. Wiszniewskiej, 1993)
1 — otwór wiertniczy, 2 — ruda bilansowa (Fec > 20%), 3 — ruda pozabilansowa (Fec > 20%), 4 — ruda pozabilansowa (Fec = 15–19,9%), 5 — skała płonna, 6 — przerwa w profilu, 7 — obszar udokumentowanego złoża

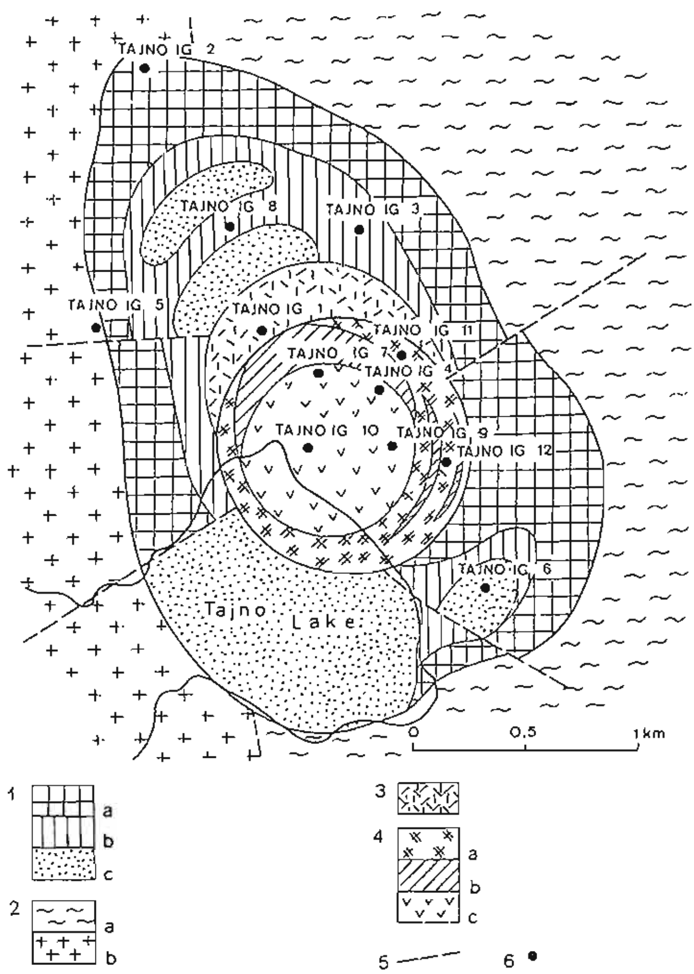


Fig. 7. Map of the Tajno Massif at the level of –500 m (after W. Ryka, 1992)
1 — intrusive rocks: a — syenites, b — intrusive breccia and fenitized ijolites, c — ijolites; 2 — Precambrian basement: a — quartzites and mica schists of Biebrza complex, b — granitoids of Mazovian complex; 3 — collapse caldera: ijolite breccia cemented with carbonatites; 4 — diatreme: a — volcanic chimney debris, b — tuffs, c — chimney breccia and carbonatites; 5 — faults; 6 — boreholes

Mapa masywu Tajna na poziomie –500 m (według W. Ryki, 1992)
1 — skały intruzywne: a — syenity, b — brekcja intruzywna i ijolity, c — ijolity; 2 — fundament prekambryjski: a — kwarcyty i łupki mikowe kompleksu Biebrzy, b — granitoidy kompleksu mazowieckiego; 3 — kaldera: brekcja ijolitowa scementowana karbonatytami; 4 — diatrema: a — rumosz w kominie wulkanicznym, b — tufy, c — brekcja kominowa i karbonatyty; 5 — uskoki; 6 — otwory wiertnicze

question contain high quantities of vanadium (up to 1% wt.), nickel and copper (0.3% wt.), chromium (0.2% wt.) and REE (up to 0.78% wt.) (L. Krzemiński *et al.*, 1989).

Veiny rocks from Łopuchowo are similar to the rocks of a nelsonite type described from Nelson County in the state of Virginia, USA.

Table 1

**Dissolved solids in groundwaters in the Suwałki region**

| Aquifer | Depth [m] | Dissolved solids [g/dm$^3$] | Production rate [m$^3$/h] |
|---|---|---|---|
| Cretaceous | 302–305 | $(Cl^-) - Na^+$<br>3 (vicinity of Gołdap) | – |
| Upper Jurassic | 400–500 | Chlorine<br>6 | 0.5–2.0 |
| Lower–Middle Jurassic | 500–600 | Chlorine<br>1 (vicinity of Augustów);<br>7 (vicinity of Gołdap) | – |
| Triassic | 600–800 | Chlorine<br>40–116 | several |
| Permian | 960–1100 | $(Cl^-) - (Br^-)$<br>110 | 1.8 |
| Cambrian–Vendian | 1600 | Chlorine<br>≈ 120 | – |

To the platform stage of development, at the close of Precambrian, multistage intrusions of central type are related.

The Ełk Massif covers about 400 km$^2$. It is circular in shape. This structure had formed in at least four stages, building ring-like intrusions of alkali granites and granodiorites, syenites, pulaskites, mariupolites and nephelinites (Fig.6). Due to the overlapping magmatic processes in faulting zones, metasomatic and hydrothermal transformations took place, leading to the concentration of useful elements. Metal-bearing zones are from several centimetres to several metres thick. They exhibit a natural radiation anomaly of mixed uranium-thorium character. The niobite content is up to 0.86%, REE to 1.4% and zircon to 4.4%. Useful minerals form independent grains of pyrochlorite, perovskite-loparite, fluorocarbonate and others or occur as isomorphic admixtures (W. Ryka, 1994).

The other interesting object, for the occurrence of carbonatites with REE elements, is the volcano-plutonic Tajno structure covering about 10 km$^2$. Its top is at a depth of 600 m. The massif is built of ijolites, cut by younger veins of microsyenites and lamprophyres. Carbonatites are shaped in veiny and veiny-stockwork forms mostly concentrated in chimney breccia as well as in pyroxenite and syenite megabreccia (Fig. 7). Three stages of formation of the carbonatites have been distinguished — early, main and late within the temperature intervals 450–320, 320–180 and below 165°C, respectively. The main stage represented by carbonatites built of calcite, fluorite, burbankite with synchizite and parisite, strontianite, silicates and sulphides, is richest in rare earth elements. Burbankite containing more lantanium than cerium is a main mineral carrying rare earth elements. In samples, the content of rare earth elements is up to 9% and within the spectrum of the REE elements, light lantanides prevail (W. Ryka, 1992).

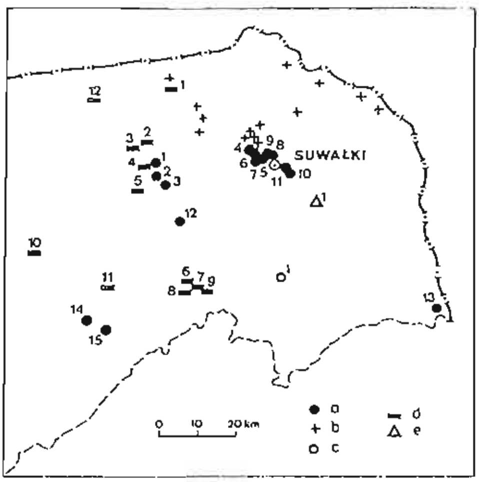


Fig. 8. Rock raw materials of the Suwałki region (after P. Brański and E. Tołkanowicz, 1993)
a — natural crushed rock deposits (1 — Stożne – Łęgowo, 2 — Łęgowo, 3 — Sedranki II, 4–7 — Potasznia I, II, III, 8 — Krzywólka II, 9 — Krzywólka – Suwałki, 10 — Sobolewo – Krzywe, 11 — Sobolewo A, 12 — Olecko Małe, 13 — Lipszczany, 14 — Woszczele – Chrzanowo, 15 — Ełk – Szyba; b — main places of eratic boulders occurrence; c — dokumented deposits of quartz sands and sands for cellusculаr concrete; d — documented and registered deposits of clayey mineral resources for building ceramics (1 — Zawiszyn, 2 — Kowale - Oleckie, 3 — Guzy, 4 — Stożne, 5 — Gordejki, 6 — Pisanica, 7 — Pisanica A, 8 — Makosieje, 9 — Czynsze, 10 — Ranty, 11 — Siedliska, 12 — Wronki Wlk.); e — deposits of lacustrine chalk: Krusznik

Złoża surowców skalnych Suwalszczyzny (według P. Brańskiego i E. Tołkanowicz, 1993)
a — udokumentowane złoża kruszywa naturalnego; b — główne miejsca występowania głazów narzutowych; c — udokumentowane złoża piasków kwarcowych i piasków do betonów komórkowych; d — udokumentowane i zarejestrowane złoża surowców ilastych ceramiki budowlanej, e — złoża szacunkowe kredy jeziornej Krusznik

## PALAEOZOIC AND QUATERNARY GROUNDWATERS

Groundwaters occurring within the whole complex of the sedimentary rocks as well as the crystalline basement are significant raw materials of the region. Sandy Cambrian and Vendian formations are an aquifer with chlorine waters of mineralization of 120 g/dm$^3$. Unfortunately the depth of their occurrence makes their exploitation impossible. Permian, Triassic, Middle and Upper Jurassic, and Cretaceous formations contain horizons of mineralized waters of alternating production rate as well (Tab. 1).

Quaternary groundwaters are young and fresh and of an infiltration origin. They are separated from the mineralized waters by the waters of the transitional zone of mixed, chlorine-hydrocarbon composition. Groundwaters with potential exploitation (average flows over 10–30 m$^3$/h) occur within the Quaternary formations exclusively (J. Mitręga *et al.*, 1993).

## QUATERNARY ROCK RAW MATERIALS

The last, but not least, type of mineral resources are rock raw materials occurring within Quaternary formations. In the Suwałki region, Quaternary sediments are from 112 to 281 m thick and represent all of the four glaciations. Most deposits are related with the Pleistocene activity of the glaciers and forms created due to their deglaciation.

The most significant mineral raw material of the Suwałki region is, at present, natural crushed rock. This material occurs in 13 documented deposits within the Suwałki –

Augustów outwash and in the Czarna Hańcza Valley within the first terrace above Wigry Lake. Several deposits have been documented near Olecko. The deposits from the Suwałki region are gravelly sand (average sand content 30–50%) or sandy gravel (50–75% sand). The documentation works have covered almost 3000 ha and the deposits contain over 680 mln t of crushed rock material. Mining is carried on at the Sobolewo A, Sobolewo B, Krzywólka – Suwałki and Potasznia I deposits. In the region of Olecko 5 deposits have been documented within the gravelly-boulder moraine (Fig. 8).

A characteristic feature of the deposits of natural crushed rocks is a high, sometimes exceeding norms, content of boulders. Pebbles 80–350 mm in diameter, making up so-called overgrain at the deposit, used for construction purposes, are of an industrial significance. Boulder and boulder-gravelly covers such as in the vicinity of Bachanowo, Hańcza, Kruszki occur over considerable areas in this region (P. Brański, E. Tołkanowicz, 1993).

Quartz sands used for calcareous-silicate bricks are important raw materials. Their deposits have been documented at the $A+B+C_1$ categories in the region of Augustów – Zatartacze and Pisz. The economic resources are over 6 mln t but due to a limited demand and protection of the landscape are not exploited.

The Main Stadial of the North-Polish Glaciation (its Pomorze Stage) is related to the deposits of clayey raw materials for construction ceramics. They occur in western parts of the Suwałki region.

The economic resources documented in 13 deposits — Gordejki, Harszyn, Ranty, Siedliska, Stożne, Wronki Wlk., Zawiszyn, Pisanica, Kowale Oleckie, Guzy, Makosieje, Czynsze, and Pisanica — are about 7.5 mln $m^3$ (S. Przeniosło, 1993). Unfortunately this is not a high quality material and only certain parts of the Stożne and Gordejki deposits contain some better kinds (P. Brański, E. Tołkanowicz, 1993).

Worthwhile are also the occurrences of lacustrine chalk and gyttja formed during the Late Pleistocene and Holocene in stagnant water basins. It is estimated that near the village of Krusznik there are 36 mln $m^3$ of them (E. Tołkanowicz, 1992).

The Suwałki region raw materials are the treasure of this land as well as the national wealth of Poland. Their proper, exploitation bearing in mind the natural beauty of the landscape of this region and its environment, plants and animals, is our duty too.

Zakład Geologii Surowców Mineralnych
Państwowego Instytutu Geologicznego
Warszawa, ul. Rakowiecka 4
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Janina WISZNIEWSKA

## ZŁOŻA SUROWCÓW MINERALNYCH NA SUWALSZCZYŹNIE

### Streszczenie

Obszar Suwalszczyzny jest bogaty w złoża surowców mineralnych. Wiele z nich znajduje się w ciągłej eksploatacji, jak surowce skalne czy zasoby wodne. Badania geofizyczne i geologiczno-poszukiwawcze, prowadzone na masywie suwalskim w celu odkrycia rud metali użytecznych, zostały uwieńczone odkryciem w rejonie Krzemianki i Udrynia rud tytanomagnetytowych w prekambryjskich skałach anortozytowo-norytowych (J. Znosko, 1962). Złoża powyższe zostały rozpoznane i udokumentowane w kategorii $C_1$ i $C_2$. Sumaryczne zasoby obu złóż wynoszą około 1,5 mld t rudy. Podobną mineralizację odkryto w rejonie anomalii magnetycznej Jeleniewa i Jeziora Okrągłego. W otworze wiertniczym Łopuchowo występują żyłowe skały apatytowo-kruszcowe (nelsonity), o podwyższonej zawartości pierwiastków ziem rzadkich (0,78%), wanadu (ponad 1%), niklu i miedzi (0,3%) i chromu (0,2%). Na południowy wschód od masywu suwalskiego znajduje się granitowo-syenitowy masyw ełcki, obejmujący ok. 400 $km^2$, w którym występują metasomatyczne strefy metalonośne o podwyższonych zawartościach REE (1,4%), cyrkonu (4,4%) i niobu (0,86%). W wulkano-plutonicznym masywie Tajna, o powierzchni 10 $km^2$, występują karbonatyty z pierwiastkami ziem rzadkich, o zawartościach dochodzących miejscami nawet do 9%. Głównym minerałem REE-nośnym jest burbankit.

Wody podziemne występują w całym kompleksie skał osadowych, jak i podłożu krystalicznym Suwalszczyzny. Wody w utworach kambru, permu, triasu, jury i kredy są zmineralizowane: chlorkowe i chlorkowo-sodowe, o zróżnicowanych dopływach. Wgłębne wody podziemne systemu czwartorzędowego są młodymi

wodami słodkimi pochodzenia infiltracyjnego. Od wód zmineralizowanych oddziela je strefa przejściowa o składzie $HCO_3^-$–$Cl^-$–$HCO_3^-$.

Ostatnim typem surowców mineralnych są surowce skalne, występujące w utworach czwartorzędu o znacznej miąższości (112–281 m). Najważniejszymi surowcami skalnymi są kruszywa naturalne udokumentowane w 13 złożach w obrębie sandru suwalsko-augustowskiego, dolinie Czarnej Hańczy i rejonie Olecka. Inne surowce skalne to piaski kwarcowe do produkcji cegły wapienno-piaskowej, popularnie zwanej silikatową (Augustów – Zatartacze), złoża surowców ilastych dla ceramiki budowlanej (Stożne, Gordejki) oraz złoża kredy jeziornej i gytii (Kruszník).

Nowa, proekologiczna wizja rozwoju Suwalszczyzny wymaga alternatywnego podejścia do planowanych inwestycji przemysłowych, wykorzystujących bogactwa naturalne tego regionu.