Serpentinite in the Śnieżnik Massif: petrology and ecological impact

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Record

Specific properties of serpentine soil in Żmijowiec result in the presence of endemic *Asplenium adulterinum* Milde and records the plant adaptation to extreme edaphic stress

Abstract

The paper presents a locality related to the occurrence of serpentinite body from the western slope of Żmijowiec in the Śnieżnik Massif. On the basis of field observations and numerous literature references, I provide a detailed geological description of this site and discuss the origin and tectonic settings of the serpentinite body. Apart from compelling geology, these rocks are site for ladder spleenwort, a rare species protected in Poland as well as in the European Union.

Keywords

serpentinite • the Orlica–Śnieżnik Dome • Śnieżnik Massif • *Asplenium adulterinum*

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1. Introduction

Ultrabasic rocks crop out in Poland exclusively in Lower Silesia. They are usually partly or completely metamorphosed and referred to as serpentinites. The majority of these rocks form relatively large massifs associated with basic bodies surrounding the Góry Sowie Massif (i.e. Ślęza Massif, Szklary Massif, Nowa Ruda Massif; Figure 1). Mentioned massifs are considered as fragments of the same Early Devonian ophiolitic body called the Central-Sudetic Ophiolite (e.g. Dubińska et al., 2004; Mazur et al., 2006; Kryza & Pin, 2010). Nevertheless, small outcrops of ultrabasites, whose origin is still discussed, are stitching various crystalline rocks of the Sudetes (Gunia et al., 1998; Smulikowski et al., 1977). In this paper, I present some basic geological and ecological features from such a small outcrop of ultrabasites (serpentinites) located on Żmijowiec (Orlica–Śnieżnik Dome, OSD). Owing to exceptional chemical composition of ultrabasites and derived soils, they often harbour a specific plant community. The Żmijowiec site provides opportunity to study all aspects of the serpentinite occurrence: the serpentinite rock, soils derived from the rock and a rare species ladder spleenwort, a plant that grows only on serpentine soils.

2. Outline geology of the Orlica–Śnieżnik Dome

The OSD is located in the easternmost part of the Central Sudetes (Figure 1). It comprises a large orthogneiss body surrounded by the metamorphosed volcano-sedimentary succession composed mainly of mica schists, paragneisses, basic and acid metavolcanics and marbles. The orthogneiss represents deformed and metamorphosed granitic body dated, using single zircon evapo-

ration and SHRIMP methods, at 520–495 Ma (Turniak et al., 2000; Kröner et al., 2001; Lange et al., 2005). Supracrustal rocks represents the volcano-sedimentary succession which is traditionally divided into the Młynowiec monotonous Formation and the Stronie variegated Formation divided by thin horizon of the light Goszów quartzites and collectively labelled as the Młynowiec–Stronie Group (Don et al., 1990). The whole volcano-sedimentary sequence is believed to form continuous succession of either Neoproterozoic to Cambrian, based on micropaleontological evidence (e.g. Gunia, 1974; Gunia & Wierchołowski, 1979), or Cambrian to Ordovician age, based on detrital-zircon geochronology (Jastrzębski et al., 2010). However, the most recent isotopic data obtained by means of U–Pb SHRIMP dating on detrital zircons indicate that these rocks do not represent a single volcano-sedimentary sequence but comprise different metasedimentary successions showing distinct maximum deposition ages: Neoproterozoic for the Młynowiec Formation, Early Cambrian for the Stronie Formation and latest Cambrian–Early Ordovician for the Goszów quartzites (Mazur et al., 2012).

Peridotites and serpentinites constitute small outcrops giving impression of stitching crystalline rocks of the OSD (Wierchołowski, 1958). For instance, they occur in the Biała Łądecka Valley or in Żmijowiec (Figure 1B, 2A), the latter is the subject of this contribution.

3. Description of the outcrop

The outcrop is located in the western slope of Żmijowiec (Śnieżnik Massif; altitude 1117 m a.s.l.; Figure 2B). It is composed of two separate serpentinite crags. Larger unit is approximately 30 m wide and 20 m high, whereas second and smaller one is situated

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Figure 1. Tectonic map of the Lower Silesian Block: (a) the northeastern part of the Bohemian Massif with the Orlica–Śnieřnik Dome; (b) the area of occurrence of serpentinite in the Orlica–Śnieřnik Dome (after Źełaźniewicz et al., 2011).

several meters north-west of the main unit and is approximately 15 m wide and 5 m high.

The outcrop in Źmijowiec was already described by Bederke (1943) and Kasza (1964), who classified the rock from this locality as serpentinite. Further research by Smulikowski et al. (1977) distinguished four varieties of the Źmijowiec serpentinite: (a) typical serpentinite, (b) serpentinite with veins of talc, (c) serpentinite with abundant dolomite and (d) tremolite-rich serpentinites

together with chlorite-tremolite rocks (the latter was also described by Wierchołowski et al., 1958). The types are described in detail in the following:

1. Typical serpentinite (according to Smulikowski et al., 1977) is a massive dark green and nearly aphanitic rock consisting mainly of antigorite and minor olivine. Iron oxides are represented mainly by magnetite randomly distributed in ground-mass (Figure 3 A, B). Rare talc or dolomitic veins crosscut the

Figure 2. Study site: (a) geological map of Żmijowiec (after Frąckiewicz & Teisseyre, (1973)); (b) view of the outcrop from red tourist trail.

serpentinite rock. Olivine was interpreted as secondary mineral by Smulikowski et al. (1977) and as relict igneous mineral by Gil (2010).

2. Serpentinite with veins of talc contains serpentine and talc as the main additional phase, whereas tremolite and dolomite are accessory phases.
3. Serpentinite with abundant dolomite contains talc and tremolite as accessory phases. Dolomite forms well-crystallised grains or microcrystalline streaks mixed with serpentine. Smulikowski et al. (1977) distinguished three varieties of this rock from greenish-black serpentinite to granular dolomite variety. These observations indicate that serpentine was replaced first by tremolite and later by dolomite during metasomatism.
4. The last type of serpentinites is represented by tremolite-rich variety. It is characterised by tremolite that fills fissures or is present as needles replacing antigorite. In some places, this type of serpentinites may be transformed into chlorite-tremolite rocks that are more abundant in iron oxides enriched in chromium (predominantly chromite; Smulikowski et al., 1977).

On the basis of textures of the serpentine group minerals, Gil (2010) divided serpentinites from Żmijowiec into serpentinites characterized by interlocking, intermediate and chrysotile-veined structure. Other ultrabasites are represented by chlorite (chlorite-tremolite) rock, uralitized orthopyroxenite and metaharzburgite. Serpentinities from Żmijowiec contain elevated amounts of Ni, Cr and Co, which reflect the primary composition of the rock and

abundance of mafic minerals enriched in these elements, that is, olivine and orthopyroxene. Enrichment in Ca, reflected by higher amounts of dolomite and tremolite in the rock, is due to the presence of hydrothermal solutions during late stage of metamorphism (Smulikowski et al., 1977).

Smulikowski et al. (1977) distinguished several types of country rocks surrounding the outcrop represented by zoisite-hornblende erlan, talc rock and amphibolite. Erlan was interpreted as a product of metamorphism of marly-dolomitic sediments in the amphibolite facies (Smulikowski et al., 1977). Alternatively, Gil (2010) classified this rock as metaharzburgite because of the presence of olivine and orthopyroxene. Additionally to previously described country rocks, Gil (2010) also distinguished biotite amphibolite with feldspar pegmatite, quartzite and micaceous schist lenses.

4. The origin and tectonic interpretation

Smulikowski et al. (1977) suggested that the Żmijowiec serpentinite represents ultrabasic magma, which was crystallised in crust and subsequently serpentinised. Afterwards, serpentine body was placed tectonically between amphibolites. Finally, rocks were subjected to metasomatism, cut by fissures and filled by secondary minerals (antigorite, chrysotile, talc, tremolite, dolomite as well as rare olivine).

On the basis of the depleted chemical character of the serpentinite (low contents of incompatible elements) and lack of clinopy-

Figure 3. Serpentinite from Żmijowiec: (a) typical sample of the rock from the outcrop; (b) serpentinite under polarizing microscope (crossed nicols; Srp, serpentine; Mag, magnetite).

roxene remnants in the rock Gil (2010) suggested that the most probable protolith of the Żmijowiec serpentinite was harzburgite, dunite and orthopyroxenite. The protolith was subsequently placed tectonically among sedimentary rocks represented probably by tuffs intercalated with clay-mudstone deposits. The maximum age of deposition is dated on circa 530 Ma (Mazur et al., 2012), which suggests that the emplacement of the protolith took place after 530 Ma. Afterwards, protolith was metasomatised and metamorphosed under the conditions of the amphibolite facies during Variscan Orogeny. In the final stage chrysotile veins crystallized during retrograde metamorphism in the sub-greenschist facies conditions (Gil, 2010).

Further constraints on the age of the Żmijowiec serpentinite come from the observation of metamorphic structures. Serpentinites, amphibolites and other rocks of the Stronie Formation are characterised by similarly oriented planar deformation structures (Gil, 2010). It suggests that serpentinites were deformed and metamorphosed during the same tectono-metamorphic event as other rocks of the Stronie Formation (Gil, 2010). The main metamorphic event in the OSD is dated on circa 340–320 Ma based on various isotopic methods, for example, $^{40}\text{Ar}/^{39}\text{Ar}$ method (Stelten-

Figure 4. Ladder spleenwort *Asplenium adnigrum* in Żmijowiec at the beginning of May in 2010.

pohl et al., 1993; Maluski et al., 1995; Gordon et al., 2005; Chopin et al., 2012). This suggests that the protolith of the Żmijowiec serpentinites was emplaced within the rocks of Stronie formation before 330 Ma (Gil, 2010). On the other hand, talc veins were not deformed and, therefore, their formation postdates the metamorphic event at 330 Ma.

5. Ladder spleenwort *A. adnigrum* Milde – rare and endangered species related with ultrabasic rocks

Ladder spleenwort grows mainly on ultrabasic rocks and is extremely rare in other habitats. The taxa was considered as European endemit, but recently new position of this plant was discovered in Canada (Klinkenberg, 2014). Ladder spleenwort grows usually on infertile soils, for example, characterised by elevated concentrations of Ni, Cr and Co, low Ca-to-Mg ratio and low concentrations of other macro elements – a typical features of serpentinite soils (Figure 4).

Ladder spleenwort *A. adnigrum* Milde (syn.: *Asplenium fallax* (Heufler) Dorfler, *Asplenium viride* Huds. var. *fallax* Heufler, *A. viride*

Figure 5. Ladder spleenwort *Asplenium adulterinum*: (a) morphological structure of the taxon; (b) the bottom side of the leaflet with sori; (c) shape of the single spore; (d) shape of the indusium (after Karpowicz, 1963).

Huds. var. *adulterinum* (Milde) Wünsche is a fern (*Aspleniaceae*) formed as a result of the intersection of the *Asplenium trichomanes* and *A. viride* (Karpowicz, 1963; Lovis & Reichstein, 1968; Reichstein, 1981). Species consists of several individually pinnate leaves up to 25 cm, which grow from short rhizome. Single leaf consists of petiole, rachis and leaflets arranged on the rachis (Figure 5A). Taxonomic feature to recognise ladder spleenwort is a colour of petiole and rachis. In mature leaves, petiole and the lower part of rachis are brown coloured; however, the peak of rachis is green. Additionally, the bottom side of the petiole and rachis have recess (shallow 'trough'). Fan-shaped leaflet are attached perpendicularly to the rachis by means of short petioles. Spores (bean-shaped) form sori covered by indusium and occur on the bottom side of the leaflets (Karpowicz, 1963 and references therein).

Phytosociological studies indicate that *A. adulterinum* constitutes characteristic species for: Cl. *Asplenietea trichomanis* (Br.-Bl. in Meier & Br.-Bl. 1934) Oberd. 1977; O. *Androsacetalia vandellii* Br.-Bl. in Meier & Br.-Bl. 1934 corr. Br.-Bl. 1948; All. *Asplenion serpentinum* Br.-Bl. & R.Tx. 1943 ex Eggler 1955; Ass. *Asplenietum serpentinum* Gauckler 1954 (Świerkosz, 2004).

A. adulterinum occurs in Poland only in Lower Silesia (Żołnierz et al., 2008). The total number of specimens is only 490. The highest abundance was observed in the Kiełczyńskie Hills, and Żmijowiec

has the smallest population in Poland (10 specimens; Żołnierz et al., 2008). The Żmijowiec location is also the highest position above sea level, where the plant was observed.

The taxon is listed in the European Union's 'habitat directive' in Appendix II and IV (code 4066; Directive, 1992). It means that the plant requires strict protection and protection needs Special Areas of Conservation appointment. Habitat of ladder spleenwort is also listed in the legal act (Appendix I, code 8220: siliceous rocky slopes with chasmophytic vegetation). In Poland, *A. adulterinum* is under strict protection and additionally has 30-m protective zones from the borders of the position (Regulation of the Environment Minister, 2014). Plant is listed also in Polish 'red book' and 'red list' for Lower Silesia. Its status of threat is EN (endangered) and CR (critical), respectively (Kaźmierczakowa et al., 2014; Kącki, 2003).

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