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The Skalice Crag: The Variscan migmatization of gneisses in the southern part of the Strzelin Massif

Abstract

The paper presents the relationships between the rocks of the Strzelin Massif: metamorphic sillimanite gneiss, anatectic pegmatite/leucogranite and igneous biotite-muscovite granite, exposed in the Skalice Crag, one of the largest natural exposures in the massif. The interpretation of these relationships enables reconstruction of the tectono-metamorphic and magmatic history of these rocks. The age data provide the time frame for their origin and evolution.

Streszczenie

Praca przedstawia relacje między skałami masywu strzelińskiego: metamorficznym gnejsem silimanitowym, anatektycznym pegmatytem/leukogranitem i magmowym granitem biotytowo-muskowitowym w Skalickich Skałach, które są jednym z największych naturalnych odsłonięć w masywie. Interpretacja tych relacji umożliwia odtworzenie tektono-metamorficznej i magmowej historii badanych skał. Przytoczone dane o wieku skał określają czasowe ramy ich dla powstania i ewolucji.

Keywords: Skalice Crag, gneisses, migmatization

1. Introduction

The southern part of the Strzelin Massif is composed mainly of sillimanite migmatic gneisses (the Nowolesie gneisses) and quartzites of the Jegłowa Beds. Mica schists, amphibolites and calc-silicate rocks are rare (Figure 1). The rocks of the whole Strzelin Massif are poorly exposed. One of the largest natural exposures is the Skalice Crag composed of sillimanite gneiss, anatectic pegmatite/leucogranite and igneous biotite-muscovite granite. Careful observation of these rocks and their interrelationships enables a reconstruction of the sequence of metamorphic, tectonic and magmatic processes of their formation.

Because of their scientific value, the Skalice Crag should be formally protected and treated as a natural monument.

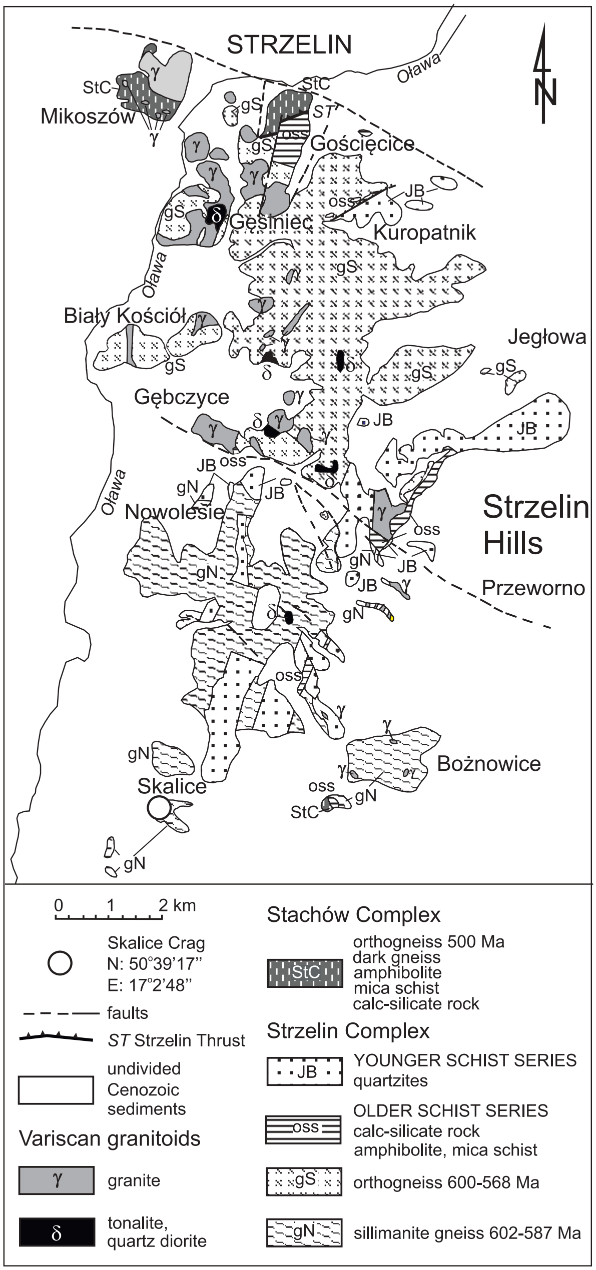

Figure 1. Geological map of the eastern part of the Strzelin Massif (after Oberc et al. 1988)

2. Description of the outcrop

The outcrop is situated in the SE outskirt of the Skalice village (GPS: N 50° 39’ 17”, E 17° 2’ 48”). The rocks form two cliffs: the south-western wall, about 50 m long and up 8 m high, and southern wall, about 20 m long and about 6 meters high. The gneiss can also be studied on top of the exposure and in isolated blocks within tens of metres south-east of the southern wall.

The sillimanite gneiss is a pale grey, fine-grained, streaky rock. Its foliation is defined by streaks of biotite plates and flat concentrations of quartz grains (Figure 2a). The matix is composed of isometric grains of quartz, microcline and plagioclase. The gneiss contains white layers, 5–10 mm thick, parallel to the foliation, composed of quartz and plagioclase. Locally, these layers are associated with concentrations of large biotite plates (Figure 2b). The most characteristic feature of the gneiss are sillimanite nodules (Figure 2c). The nodules are elliptical or circular, 5 mm to 2 cm in diameter, and up to 0.5 mm thick. The nodules are essentially made of quartz and sillimanite, the latter in the form of fibrolite mats or prismatic grains. Some nodules are surrounded by biotite (Figure 2d). Because of the high quartz contents, the nodules tend to resist weathering and they are very well visible as knots standing out of the rock surfaces (Figure 2e). In the north-western part of the outcrop, one can observe that the contents and size of nodules differ in particular layers of the gneiss (Figure 2f). Some layers contain closely packed large nodules, in others nodules are rare and small. The nodules are either parallel or oblique to the foliation. The long axes of nodules are parallel to the lineation.

The penetrative gneiss foliation is oriented 240/40 SE — 290/25 SW, the lineation plunges to S. The gneiss, together with white quartz-feldspar layers, have been deformed into open folds (Figures 2c, 3a). The axes of these folds are oriented 190/30 — 200/35. The sillimanite nodules are parallel to the axial planes of these folds and oblique or paralell to the foliation on the limbs (Figure 2c). The nodules define younger, nonpenetrative foliation S, oriented 240/40 SE — 210/25 SE (Figure 2c, f). Apart from the foliation, lineation and folds, tectonic structures are represented also by extensional crenulation cleavage showing a top-to-S and SSW sense of shear. C’–type shear bands are associated with pegmatite (Figure 3b).

The sillimanite gneiss has been intruded by dykes, nests and small bodies of pegmatite and leucogranite (Figure 3c), both composed of quartz, plagioclase, microcline and, occasionally, biotite and muscovite. The pegmatite and leucogranite contain sharp-edged fragments (rafts) of gneiss (Figure 2b). The foliation in such fragments usually shows orientation different from the foliation in larger domains of the gneiss. The leucogranite contains also disaggregated fragments of gneisses which can be traced as biotite schlieren or even as only sillimanite nodules (Figure 3d). In the pegmatite, feldspars grains were covered with bunches of sillimanite (Figure 3e). This sillimanite represents its second generation, younger than sillimanite forming the nodules.

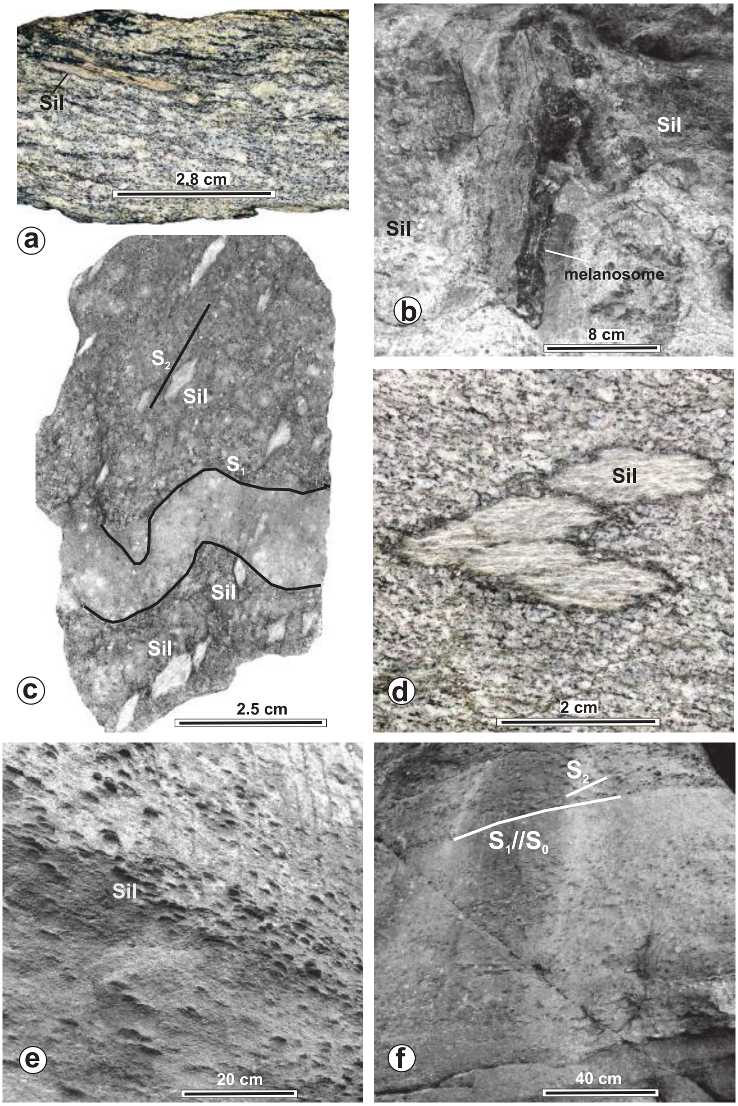

Figure 2. The Skalice Crag. a — Sillimanite gneiss (natural size): strongly flattened sillimanite (Sil) nodules are oblique (10°) to the foliation defined by streaks of biotite plates; b — The raft of the sillimanite gneiss surrounded by leucogranite; the foliation in raft is steeper than the foliation in larger domains of gneisses (e.g. Figure 2f). Melanosome composed of large biotite plates is parallel to the foliation; c — Sillimanite gneiss (natural size): white quartz-feldspar layer defining the S_1 foliation was deformed into open fold; sillimanite nodules parallel the axial plane of fold and are oblique to the foliation on the limbs define the S_2 foliation; d — Sillimanite (Sil) nodules of quartz and sillimanite (fibrolite) surrounded by biotite; e — Sillmanite nodules visible as knots of 2 cm long standing out of the rock surfaces; f — Sillimanite gneiss: particular layers of gneiss differ in the contents and size of nodules; the upper layer contains closely packed and large nodules, in the lower layer nodules are rare and small. The boundary between layers defines S_0 surface parallel to the S_1 metamorphic foliation. The sillimanite nodules define younger, nonpenetrative axial planar foliation S_2

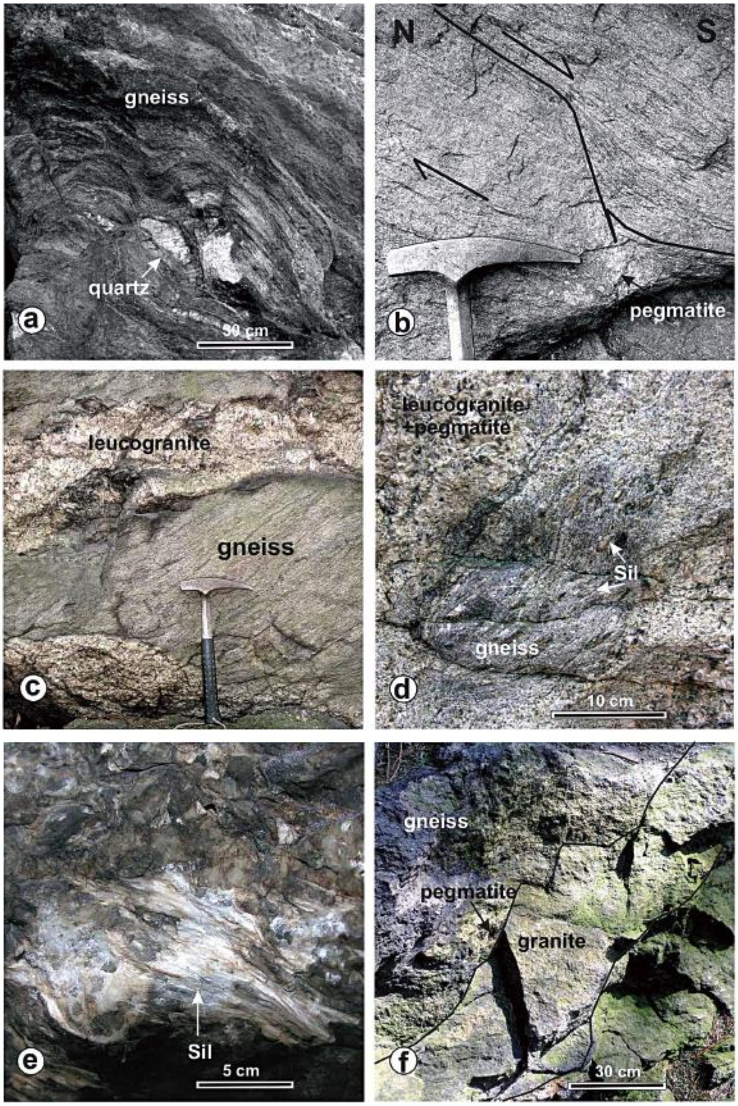

Figure 3. The Skalice Crag. a — Folds in the sillimanite gneiss with small quartz body in the centers; b — Extensional crenulation cleavage: C'-type shear bands are associated with pegmatite; c — The sillimanite gneiss intruded by dykes of pegmatite and leucogranite; d — Leucogranite containing partly melted fragment of gneiss showing traces of foliation and sillimanite nodules; e — Feldspars grains in pegmatite covered with bunches of sillimanite II; f — The gneiss and pegmatite cut by a dyke of the biotite-muscovite granite

The gneiss and pegmatite exposed in the southern part of the outcrop are cut by an E-W striking dyke of the fine-grained biotite-muscovite granite, about 30 cm thick (Figure 3f).

3. Interpretation of the field data: sequence of metamorphic/anatectic, tectonic and igneous processes

I. The oldest rock in the outcrop is the fine-grained gneiss with sillimanite nodules. The high sillimanite contents reflects the high Al-contents in the rocks. The gneiss layers differ in contents and size of sillimanite nodules (Figure 2f). It suggests that particular layers of the gneiss contain different contents of Al and that these differences reflect primary compositional features of the gneiss protolith. Such Al contents differences are more typical of clastic sediments, locally enriched in clay minerals, rather than magmatic rocks.

II. The surfaces separating layers of different sillimanite contents could be, tentatively, interpreted as the S_0 primary foliation. The penetrative gneiss foliation, defined by biotite and quartz (mostly?) parallel to S_0, represents secondary, metamorphic foliation S_1 (Figure 2f). Biotite defines also the L_1 lineation.

III. The white quartz-feldspar layers that follow the S_1 foliation are probably relatively younger than this foliation. The white layers showing granitic composition and accompanying biotite selvages (Figure 2b) can be interpreted as leucosome and melanosome, respectively, and as evidence of the first stage of migmatization, which took place after metamorphism (M_1) and deformation (D_1) that produced the S_1 foliation. The scarcity of leucosomes and melanosomes suggests that the migmatization was not very advanced during the first stage.

IV. The folds which deform the S_1 foliation resulted from the D_2 deformation (F_2 folds). The sillimanite nodules, parallel to the axial planes of the F_2 folds (Figure 2c), originated in the late stage of the D_2 deformation. The nodules define the younger, nonpenetrative axial planar foliation S_2 (Figure 2c, f).

V. The pegmatite and leucogranite are younger than the gneiss. The gneiss forming isolated rafts in the pegmatite is deformed into folds and contains sillimanite nodules. It means that the pegmatite and leucogranite are not only younger than the gneiss, but also younger than its deformation and the sillimanite nodules. The magmatic "appearance" of the leucogranite and pegmatite suggests that they crystallized from melt. This is supported by the observed different orientation of the foliation in particular gneiss rafts which point to their rotation in the melt. The sharp contacts between the gneiss, and pegmatite and leucogranite indicate that the melts were delivered from outside, probably from deeper parts of the metamorphic complex. The lobate character of borders of the leucogranite and pegmatite bodies, together with the lack of deformation structures in both rocks, suggest that their emplacement took place without tectonic control. The pegmatite and leucogranite may be interpreted as products of the second stage of migmatization.

VI. The extensional structures in the gneiss are probably older than or contemporaneous with the second stage of migmatization This supposition is evidenced by the crystallization of quartz and feldspars along the shear bands of extensional crenulation cleavage (Figure 3b).

VII. The crystallization of sillimanite II was stimulated by a week deformation D_3 which facilitated migration of Al rich fluids.

VIII. The dyke of the biotite-muscovite granite in the southern part of the outcrop cuts both the gneiss and pegmatite. It means that this granite is the youngest rocks in the exposure and that the pegmatite is older and not genetically connected with the granite.

4. Geochronological and thermobarometric data

I. Zircons from the Skalice sillimanite gneiss were dated by the SHRIMP method at 602 ±7 Ma and 587 ±4 Ma ($^{206}Pb/^{238}U$ ages; Klimas 2008; Klimas et al. 2009). These ages were interpreted as documenting "intense metamorphic and anatectic tectonothermal events during the Neoproterozoic" (Klimas et al. 2009). Mazur et al. (2010) dated zircon from the Skalice gneiss at 575 ±15 Ma (SHRIMP method, $^{207}Pb/^{206}Pb$ ages) and considered this age to reflect the time of the emplacement of the granitic protolith of the gneiss. No zircons of Variscan ages in the sillimanite gneiss from Skalice have been reported.

II. Unpublished SHRIMP age data from the pegmatite and in biotite-muscovite granite dyke from Skalice confirm the presence of zircons of Variscan ages. The zircons from the biotite-muscovite granite are younger than zircons from the pegmatite.

Comment: The age data generally confirm the age sequence of the tectono-thermal events (protolith — migmatization I — migmatization II — granitic magmatism) established based on field observations. They also point to the Variscan age of migmatization II (pegmatite and leucogranite) and of the biotite-muscovite granite. However, the zircon age data do not answer the question about the age of migmatization producing leucosomes and melanosomes: was it the Variscan migmatization I, or was it neo-Proterozoic migmatization as suggested by the zircon ages and the lack of Variscan-aged zircons in the sillimanite gneiss (Klimas et al. 2009)? Theoretically, there could have been two migmatizations: the neo-Proterozic migmatization, and Variscan migmatization (I and II). The neo-Proterozoic migmatization is indicated by the zircon ages but migmatic and tectonic structures connected with that hypothetical process have not been preserved. Variscan migmatization I produced leucosomes and melanosones deformed by Variscan tectonic structures recorded in all metamorphic rocks in the Strzelin Massif; however, Variscan migmatization I is not confirmed by zircon ages. The lack of such zircons might have been caused by small amount of melt produced by anatexis (leucosomes and melanosomes are rare).

III. The P-Tconditions during migmatization I in the sillimanite gneiss north of Skalice were estimated at T = ~720º (garnet-biotite thermometer, Ferry and Spear 1978) and P = ~6.5-5.0 kb (Ghent 1976; Ghent et al. 1979). Migmatization II took place at T = 600ºC (garnet+biotite thermometer, Ferry and Spear 1978) and P = 3kb (plagioclase+biotite+garnet +muscovite geobarometer, Ghent and Stout 1981) (Oberc-Dziedzic 1999).

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