Geologia Sudetica, 2014, 42: 125–136.

The CETeG 2014 excursion to crystalline basement of the Orlica–Śnieżnik Dome, the Sudetes

Stop 1.1

Metabasalts of the western part of the OSD

Leaders: Jacek Szczepański (UWr) & Sławomir Ilnicki (UW)
Topic: Geochemical record in the metabasalts of the Bystrzyckie Mts. and its geodynamic significance
Location: N50°11'43", E16°37'18"; road from Domaszków to Zieleniec, in the vicinity of the Szczerba castle ruins

The mafic metavolcanics in the vicinity of Gniewoszów occur as relatively large, up to 50–70 m thick, bodies hosted by supracrustal rocks of the Stronie–Młynowiec Group. Near Szczerba castle (south of Gniewoszów), metabasites are found in small isolated outcrops forming a roughly complete, ca. 70–100 m thick, section. Its uppermost portion reveals relics of pillow lava (Fig. 1), which can be visible in mutually perpendicular sections. Particular pillows are composed of fine-grained metabasalt and show various degrees of flattening resulting from strain accommodated during deformation. The pillows reach from several tens of centimeters up to 2–3 m in diameter (Szczepański, 2010; Ilnicki *et al.*, 2013; Fig. 1A–C).

The metabasites are fine grained sometimes porphyroblastic rocks with moderately to well-developed foliation dipping to SW under moderate angles and mineral lineation gently dipping S. They are composed mainly of zoned Ca-amphibole ranging from actinolite in the cores to tschermakite or even pargasite at the rims, and plagioclase of oligoclase-to-andesine ($An_{23\text{-}33}$) composition at the rims, with albitic cores. Plagioclase porphyroblasts often contain inclusions of actinolite and ilmenite, sometimes forming sigmoidal or straight trails. Chlorite, epidote and ilmenite are subordinate phases, with quartz, biotite, apatite, titanite, rutile, zircon and potassium feldspar as accessories. The rocks document a westward transition from greenschist to amphibolite-epidote or amphibolite facies conditions, with retrograde metamorphism under greenschist facies conditions. The peak metamorphic conditions at Szczerba castle correspond to the garnet zone and yielded 560–570°C at 6.4 kbar. This stage was preceded by the M1 event at 450–500°C and 1.8–4.2 kbar and followed by retrogression under greenschist facies conditions.

The metabasites are generally classified as basalts and on several classification diagrams show mostly tholeiitic affinity. These rocks have relatively high Zr/Nb (21–27) and La/Nb (1.25–2.51) and relatively low Ti/V (32–45), Zr/Y (2.9–3.9) and Nb/Yb (1.2–1.9) values (Fig. 2). Moreover, chondrite-normalized and the primitive mantle-normalized patterns are generally nearly flat, only gently sloping with

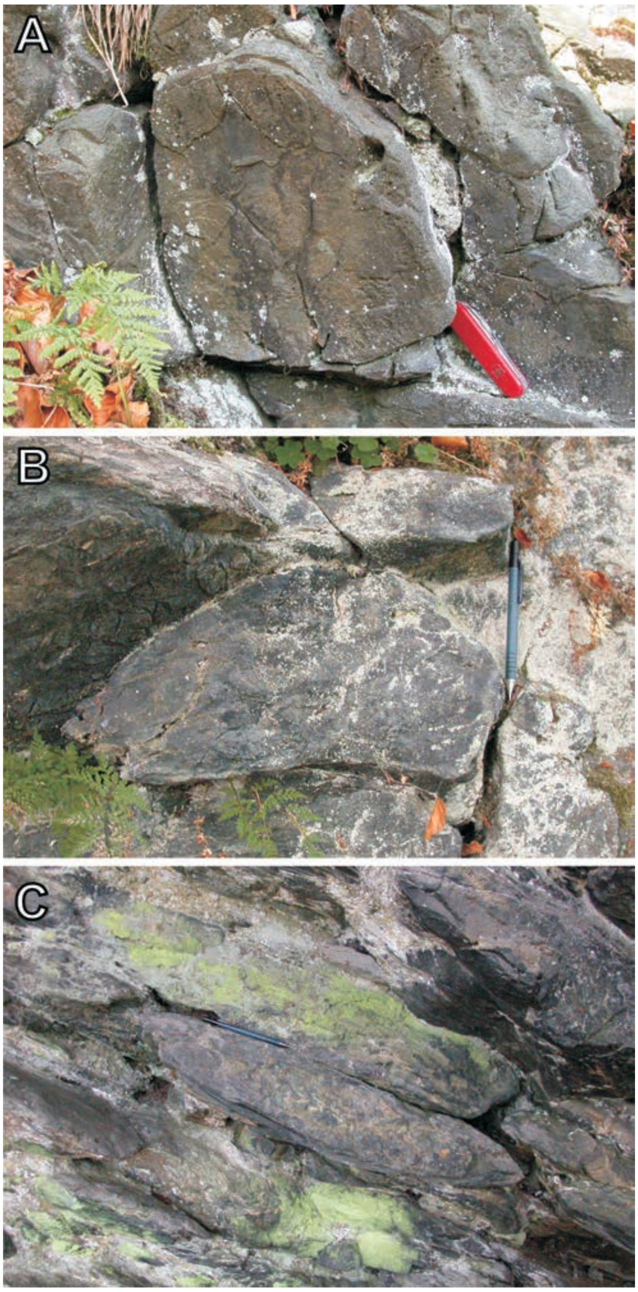

Fig. 1. Field photographs of the metabasalts with preserved variously deformed pillows.

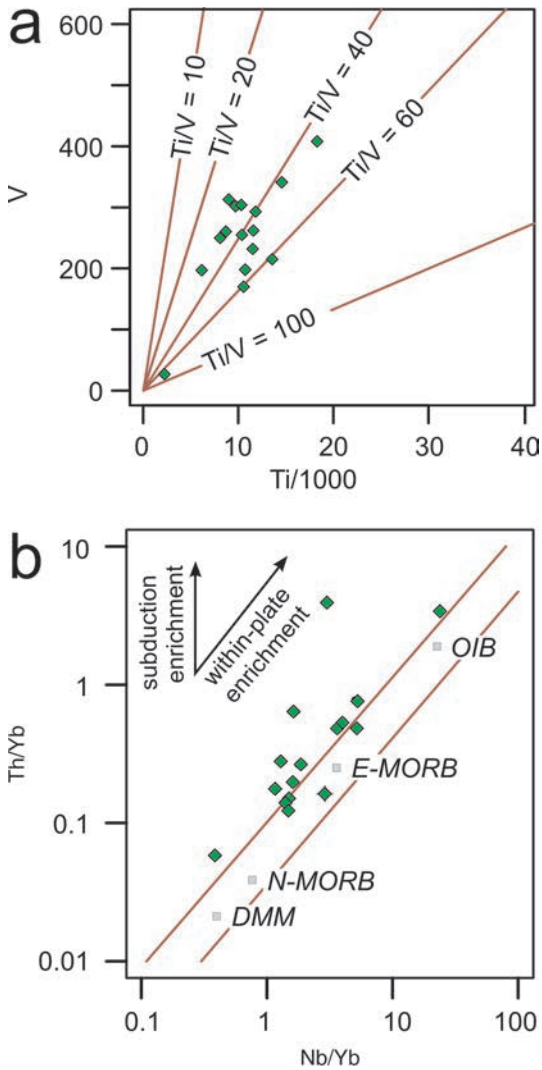

Fig. 2. **a.** The V-Ti diagram of Shervais (1982). BAB – back-arc basin basalts, CFB – continental flood basalts, IAT – island arc tholeiites, N-MORB – normal MORB, OIB – ocean island basalts. **b.** Th/Yb versus Nb/Yb diagram (Pearce & Peate, 1995) for the Bystrzyckie metabasites. Heavy diagonal lines of constant Th/Nb show the array of basalts from non-subduction settings derived from either enriched (i.e. OIB) or depleted mantle (i.e. MORB) sources. The OIB, PM, E-MORB and N-MORB values from Sun and McDonough (1989), DMM values from Workman and Hart (2005).

slight LREE-enrichment ($[La/Yb]_{CN}$ = 1.3–1.9) and noticeable negative anomalies for P and Ti. A weak fractionation of MREE from HREE ($[Tb/Yb]_{CN}$ = 1.2–1.4) suggest the presence of residual spinel in the mantle source. The samples display depletion of the most incompatible elements (Th-Nb) relative to La and have Th/Nb ratios of 0.08–0.14, whilst their LREE profile remains flat (at ~7–10 × PM). N-MORB-normalized profiles also show distinct negative Nb anomalies relative to Th and La. Some of the analyzed samples show more LREE-enriched compositions ($[La/Yb]_{CN}$ = 1.8–2.9) coupled with a distinct though variable Nb depletion and Th enrichment, and a slight Zr depletion on PM-normalized plots. This feature is reflected in their high Th/Nb ratio (0.15–0.39). However, their MREE- HREE profiles are the same as for the rest of the samples.

The chemical features of metabasalts from Gniewoszów vicinity are similar to mildly-enriched N-MORB (Fig. 2). Contrary to typical N-MORBs, these metabasites are also characterized by Nb (± Ti) depletion. However, independently of the Nb negative anomaly, the initial Nd isotope signatures (εNd_{530}) are positive (+0.2 to +6.7) and imply the mantle source markedly depleted in Nd relative to Sm on a time-integrated basis.

The effects of magma-crust interaction are detectable, though variable, in the Bystrzyckie metabasalts. Some samples display negative Nb, Ti and P anomalies with variable Th, LREE enrichment on primitive mantle normalized plots. Despite some features consistent with crustal contamination (e.g., the elevated Th/Yb values and position of the studied rocks above the mantle array in Fig. 3b, the values of La/Nb > 1.5, a negative correlation between εNd_{530} and La/Nb or Th/Nb), modelling of the AFC processes revealed that crustal contamination alone cannot adequately account for the geochemical character of the the Bystrzyckie metabasalts. Instead, it is postulated that these rocks may bear a record of processes operating in the active subduction zone. Contribution of slab-derived components is indicated by negative Zr anomalies, Zr/Nb, Nb/Th and La/Nb ratios approaching values typical of arc magmas, or by [Hf/Sm] PM vs. [Ta/La]PM systematics consistent with subduction- derived metasomatism (Ilnicki *et al.*, 2013). Likewise, Th/Yb ratios are high and trend very steeply on the Th/Yb vs Nb/Yb diagram (Fig. 2b). According to (Pearce, 2008), such a trend is supposed to reflect the influence of subducted sediment on magma compositions, especially those derived from depleted mantle sources.

On several discrimination diagrams the rocks show affinities to either E-MORB–to–N-MORB or back arc basin basalts (BABB). Highly variable degree of both subduction-related input and mantle source enrichment (shortly prior to melt generation) observed in the Bystrzyckie metabasites is typical of supra-subduction extensional regime. Thus the Bystrzyckie mafic metavolcanics are currently interpreted as a MOR-type basalts that originated in a back-arc setting related to an unspecified subduction event. However, geochemical affinities of the these rocks coupled with age and geochemical constraints from the contemporaneous Stronie–Młynowiec Group (Stop 1.3) seemingly relate the studied magmatic episode to the model of Linnemann *et al.* (2008) of the subduction zone extinction at the turn of the Cadomian orogeny and incipient Early Palaeozoic rifting of Gondwana.

Stop 1.2

Metarhyolites of the Stronie Formation in the western limb of the Orlica–Śnieżnik Dome

Leaders: Andrzej Żelaźniewicz (ING PAN) & Mentor Murtezi (ING PAN)
Topic: The ~500 Ma metarhyolites, bimodal volcanism and multiple deformation of metavolcanogenic rocks.
Location: N50°11'39", E16°37'15"; road from Domaszków to Zieleniec, in the vicinity of the Szczerba castle ruins.

Felsic metavolcanogenic rocks in the Gniewoszów area form elongated discontinuous bodies or lenses, up to some hundreds metres long and several tens of metres thick, within mica schists of the Stronie Formation. These are acid, medium-grained rocks mainly composed of quartz, K-feldspar, chlorite, muscovite and opaque minerals. The phyllosilicate content can vary in these rocks, so that they form either massive- or mica-bearing schistose rocks interpreted as lavas and tuffites, respectively.

On the Nb/Y vs Zr/TiO_2 diagram, the rocks from Gniewoszów fall between the rhyolite and rhyodacite/dacite fields (Murtezi, 2006). Geochemical study on these rocks presented by this author show that the massive acid metavolcanic rocks from this locality reveal a strong negative Eu anomaly, whereas mica-bearing samples are characterized by lower Eu anomaly (Fig. 1A). A positive Ce anomaly may indicate some admixture of shallow water marine sediments in the protolith. The high concentration of strongly incompatible elements such as REE and enrichment in large-ion-litophile elements suggest affinities to continental crust. On the other hand, the diagrams discriminating tectonic environment point to volcanic arc setting (Fig. 1B) and the high Th/Ta ratios, negative Nb and Ta anomalies, and low Ti, Zr and Hf also suggest a suprasubduction setting. Such ambiguous characteristics may indicate an ensialic rift or a back-arc extensional environment (Murtezi, 2006). The Gniewoszów metarhyolites are equivalent to S- and I-type granites and do not show affinity to A-type granites (Fig. 1C).

The U-Pb SHRIMP zircon study revealed that the massive variety is reach in clear, colourless, and large (up to 300 µm long), euhedral zircon crystals. The zircons commonly have clear oscillatory zoning. The concordia age of 500.7 ± 2.7 Ma was established for 16 analyses of these zircons (Murtezi, 2005). These zircons crystallized from rhyolitic melt just before or at the time of volcanic eruptions. Thus, this age is interpreted as reflecting the timing of deposition of the adjacent metasedimentary Stronie Formation rocks. Another, much less populous, group of zircons provided the discordia line intercepting with the concordia curve at points constraining the present time and the age of 581 ± 49 Ma. Some of the crystals have rims U-rich darker in CL. An U-Pb age of ~328Ma was obtained for one analytical point. Two inherited Archaean ages (2.8 and 3.0 Ga) were obtained. Several smaller, yellowish crystals with ovoidal shape can be interpreted as a subordinate detrital component (Murtezi, 2005).

The conventional thermobarometry applied to garnet-bearing mica schists that surround the visited outcrop indicate that these rocks experienced the temperature peak metamorphism at 500–550°C and 6–7 kbar (Murtezi, 2006; Jastrzębski, 2009), which almost perfectly fits the data obtained for the metabasites (Szczepański & Ilnicki, Stop 1.1).

In Stop 1.2, felsic metavolcanogenic rocks are exposed at the road-cut and in crags on the forested hill slope. The metabasites that occur at the foothill of the Szczerbiec castle can be also observed on the northern side of the road. There are massive rocks, former lava flow, set in more schistose ones that pass into felsic tuffitic rocks, which provides evidence of bimodal magmatism. In the transitional zone, metatuffitic schists developed lighter and darker layering (Fig. 2A).

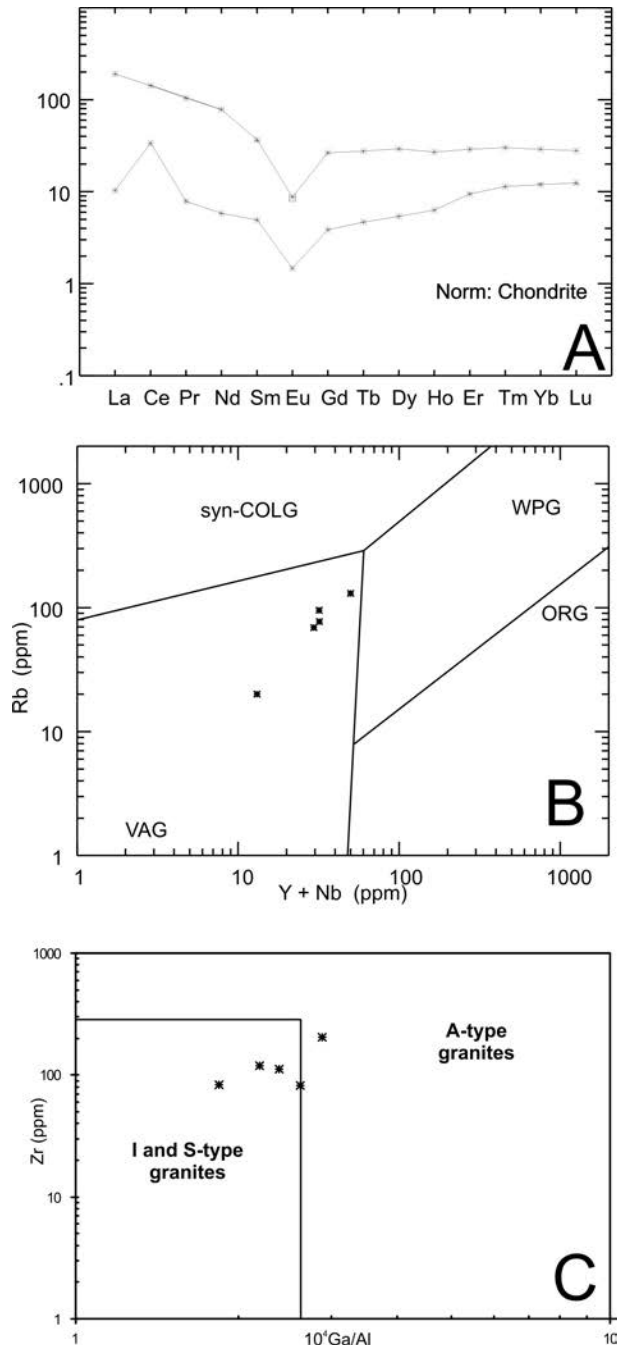

Fig. 1. Geochemistry of metarhyolites in Gniewoszów. A – the chondrite-normalised (values after Anders & Grevesse, 1989) REE variation patterns of the massive leptites; B – the Rb – (Y+Nb) tectonic environment discrimination diagrams (after Pearce *et al.*, 1984). VAG – volcanic-arc granites; syn-COLG – syn-collisional granites; WPG – within-plate granites; ORG – ocean-ridge granites; C – the Ga/Al-Zr discrimination of A-type versus other granite types (after Whalen *et al.*, 1987).

A gross contact between the two lithologies is generally subvertical and involved in large-scale folds with the axes striking in the WNW direction and the axial plane foliation dipping at a low to medium angle to the SW (Fig. 3A). Mesoscopic folds (Fig. 2A) in felsic and transitional rocks conform the elongation of the pillows in the metabasites.

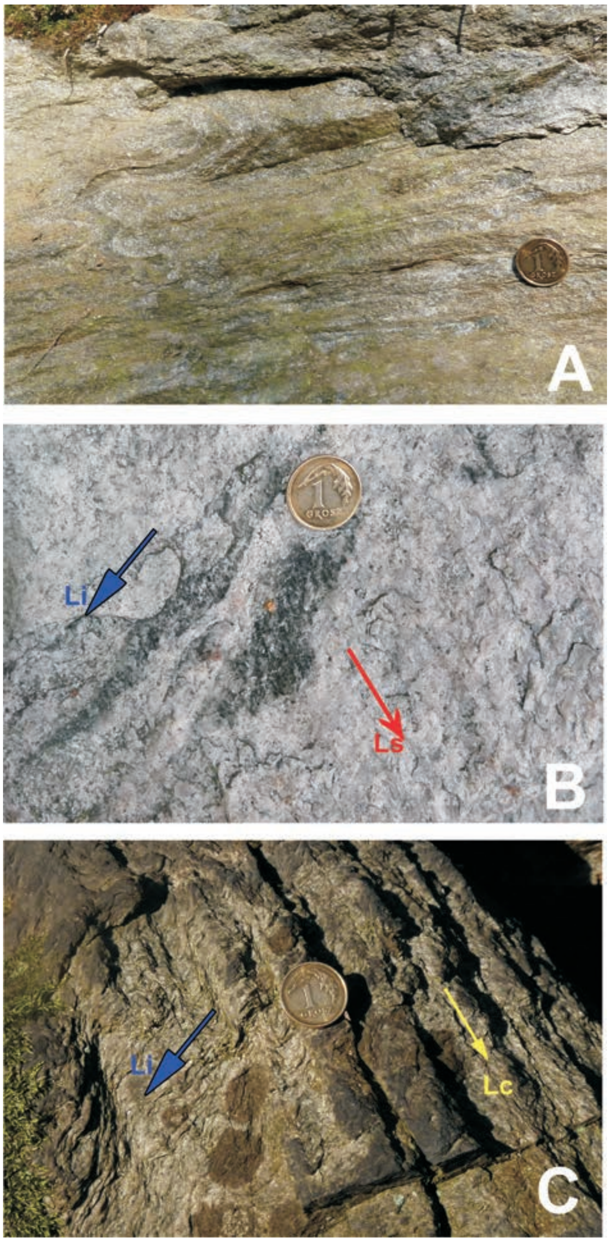

Fig. 2. Structural features in schistose felsic metavolcanic rocks in Gniewoszów. A – WNW-plunging folds F_2 and intersection lineation L_2; B – W-plunging intersection lineation L_2 (L_i, blue arrow) overprinted by S-plunging stretching lineation L_3 (L_s, red arrow); C – L_2 intersection lineation (L_i, blue arrow) refolded by SSE-plunging crenulation folds F_5 (L_c, yellow arrow) with NNW-trending subvertical crenulation planes S_{cr}

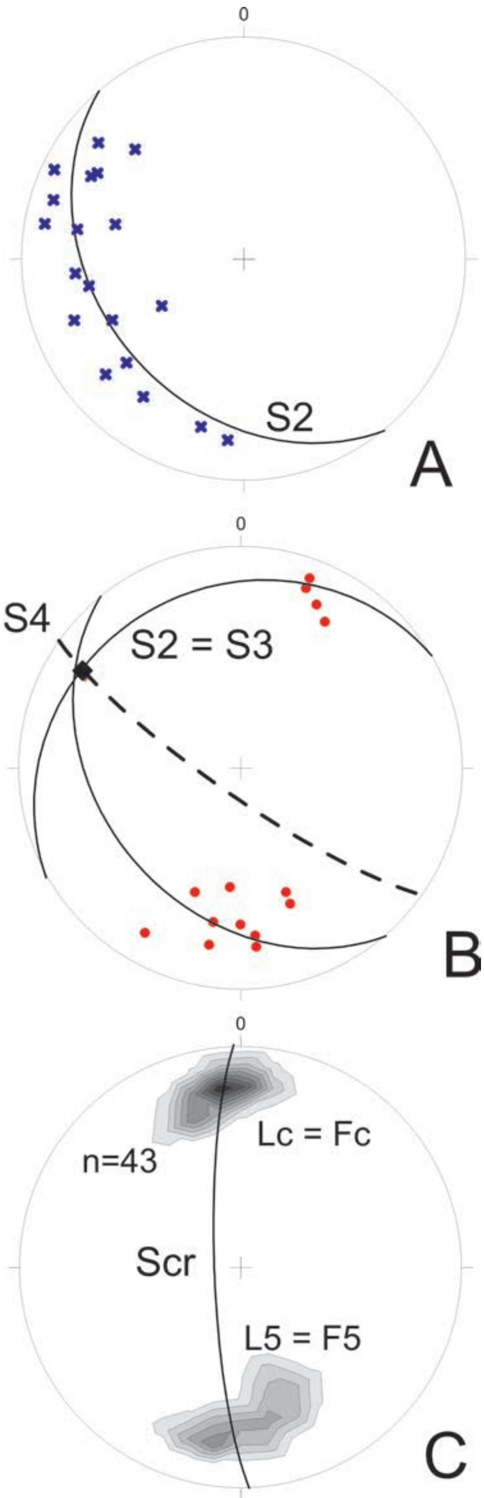

Fig. 3. Orientation of structural elements (lower hemisphere). A – F_2 fold axes and L_2 (L_i) intersection lineation (crosses) with trace of S_2 foliation; B – L_3 stretching/mineral lineation and F_4 open fold axis; C – L_5 crenulation lineation and F_5 crenulation folds with trace of the axial surface S_5

The small-scale folds and the S_1/S_2 intersection lineation (Fig. 2B) in the schistose felsic rocks are considerably scattered in the foliation plane (Fig. 3A) and overprinted by stretching lineation L_3 plunging to the south. The lineation testifies the N–S oriented shearing that affected the earlier folded pile in particular along the earlier foliation S_2 which was in the way rejuvenated and thus labelled $_{S2–3}$. A new structural element that developed was the stretching lineation with mainly a top-the-S kinematics, whereas the shearing gave rise to an internal rotation of the L_2/F_2 linear features in the foliation $S_{2–3}$ (Fig. 3A, B). During two subsequent deformational events the older planar and linear structures were refolded by open to tight, SW-vergent folds F_4 with NW–SE oriented axes (Fig. 3B) and finally by semi-brittle crenulation (chevron-type) folds F_5 that have sub-vertical N–S striking crenulation planes (Fig. 2C, 3C).

In the Gniewoszów area, the felsic and mafic rocks occur next to each other and show transitions, which documents bimodal volcanism accompanying pelitic sedimentation of the Stronie Formation at ~500 Ma. The metabasites with a mildly-enriched N-MORB geochemical signature poured on the basin floor as pillow lavas that were covered by acid mostly tuffitic and less frequent lava material. Such Middle to Late Cambrian magmatic activity likely occurred in a back-arc setting related presumably to an unspecified subduction event. Mantle origin of the basic rocks and continental affinity of the felsic rocks suggest a scenario of mafic underplating giving rise to localized melting of the continental crust. Then the lithologies were taken into large-scale, W/WNW-trending overturned to recumbent folding at a depth corresponding to 6–7 kbar at 500–570°C. The folding event was followed under similar conditions by shearing that rejuvenated the axial plane foliation of the earlier folds. In the Gniewoszów area, the kinematics of the shearing was dominantly of a top-to-the-S sense of movement. Large-scale refolding on the NW-trending axes with the SW vergence preceded brittle-ductile folding with the E-vergence of the N–S oriented crenulation folds.

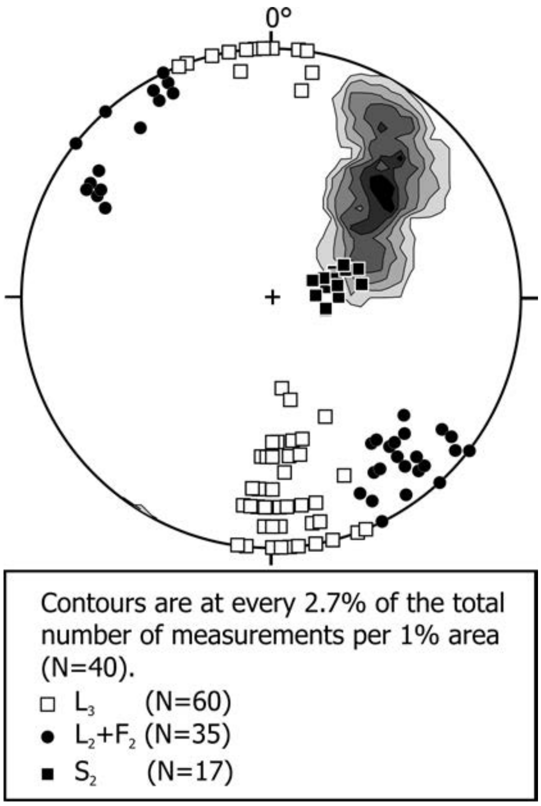

Fig. 1. Synoptic stereogram showing scatter of foliation S0+1 along a great circle (grey dotted line) with an axis of ca. 298/22 (white star). Black squares – normal to S_2 foliation; black circles – L_2 lineation and axes of F_2 folds; white squares – L_3 lineation; white star – axis of great circle girdle of foliation S_{0+1}. N – number of measurements. Equal-area net, lower hemisphere.

Stop 1.3

Stronie–Młynowiec Group

Leaders: Jacek Szczepański (UWr) & Sławomir Ilnicki (UW)
Topic: Structural and chemical records in the metasedimentary rocks of the western part of the OSD and their geodynamic context
Location: N50°17'08", E16°36'07"; road from Ponikwa to Bystrzyca Kłodzka

The metasedimentary sequence in the Młoty Unit is dominated by monotonous paragneisses with rare inliers of metabasalts and micaschists. Paragneisses cropping out near Wyszki are grey, mainly medium grained rocks comprising plagioclase, white mica, biotite, garnet and quartz. Common accessories are chlorite, apatite, zircon, rutile and opaque minerals.

These rocks bear a record of three deformation episodes. The oldest preserved planar structure in the Młoty Unit is represented by S_1 foliation. Normal to S_1 plot on a great circle with an axis of ca. 298/22 (Fig. 1). S_1 planes are defined by parallel alignment of laminae varying by colour and thickness. Difference in colour results from changing proportion of quartz as well as micas and feldspars in respective laminae. These features indicate that observed foliation is most probably parallel to original sedimentary bedding S_0. However, in microscale this foliation is also defined by parallel alignment of micas and flattened quartz grains. Moreover, in remaining outcrops of the Młoty Unit this foliation is mostly preserved as inclusion trails conserved within plagioclase porphyroblasts or in microlithons between younger S_2 foliation planes. This may suggest that in the Młoty Unit S_0 bedding is parallel to S_1 foliation. The foliation S_{0+1} is deformed by asymmetric F_2 folds with axial planes gently dipping to SW. Their axes are gently dipping to NW or SE (Fig. 1). Parallel to axial planes of these folds S_2 foliation was developed. This younger foliation in the whole area of the Młoty Unit do not show any scatter and is located on the great-circle of the S_1 foliation (Fig. 1) confirming that S_2 planes could originate as an axial cleavage of F_2 folds. Furthermore, on S_2 planes intersection lineation L_2 oriented parallel to axes of F_2 folds was developed (Fig. 1). Effects of the D_3 episode in the Młoty Unit are preserved only locally and not recorded in the Wyszki locality. During D_3 deformation S_2 planes were reactivated, leading to formation of complex S_{2+3} foliation, with mineral lineation L_3 trending subhorizontally N–S (Fig. 1). The latter structure is defined by parallel alignment of micas and quartzo-feldspar aggregates. Sections parallel to L_3 linea- tion and perpendicular to S_{2+3} foliation scarcely reveal a set of kinematic indicators pointing to top-to-N shearing during D_3 episode.

The monotonous metagreywacke from the Wyszki yielded Precambrian age spectra similar to those that are characteristic of the Cadomian terranes (e.g. Linnemann *et al.*, 2008): (1) Archaean and Palaeoproterozoic zircons scattered between 2167 and 1867 Ma, and (2) abundant Neoproterozoic zircons dated at 803–577 Ma. The estimated maximum sedimentation age is 569 ± 8 Ma (Mazur *et al.*, 2013). Importantly, lithological similarities and detrital zircon age spectra suggest that paragneisses of the Młoty Unit

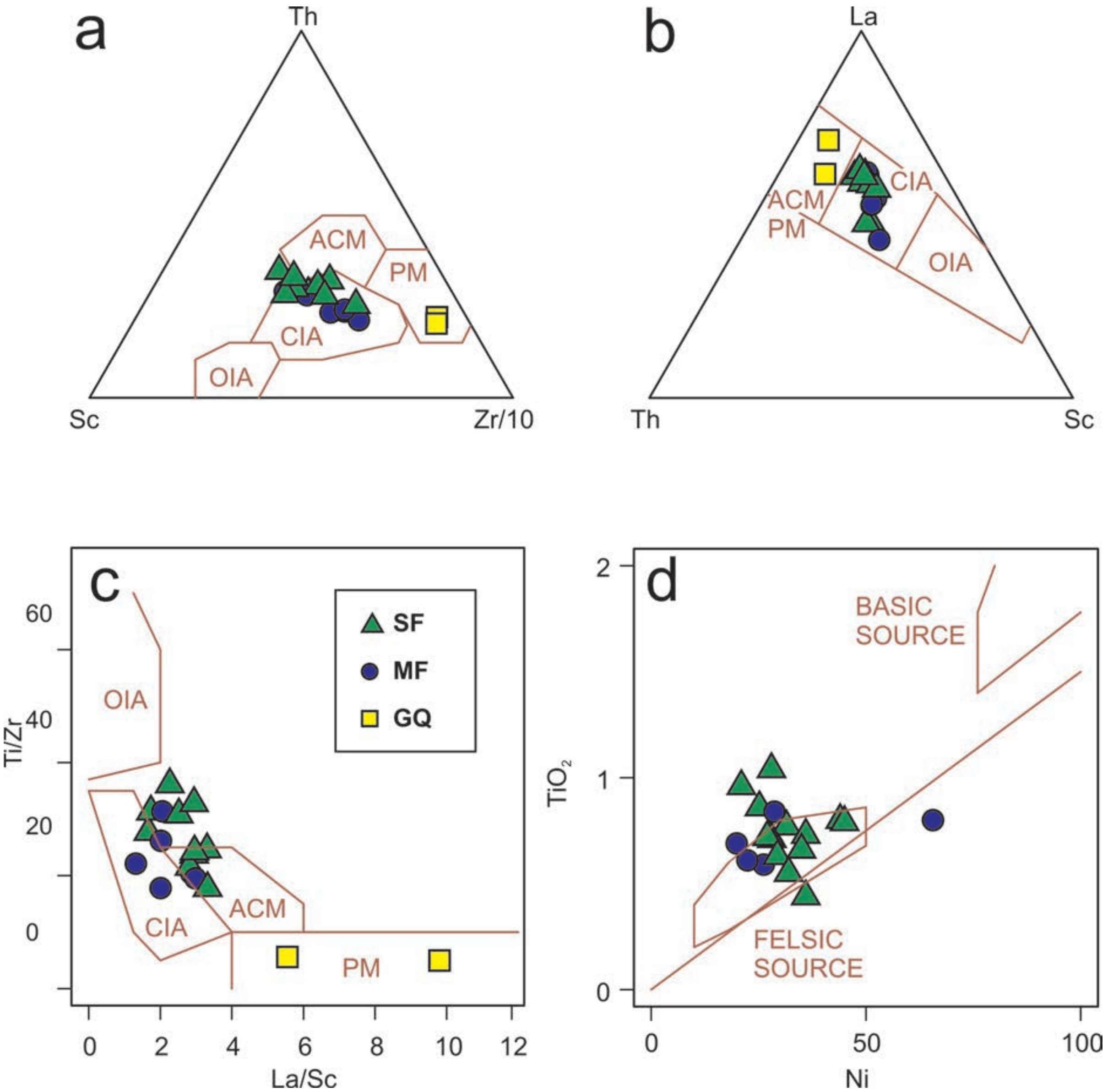

Fig. 2. **a–c** – discrimination diagrams showing tectonic setting of deposition of the protoliths to the OSD metasediments. Diagrams after Bhatia and Crook 1986; d – binary plot TiO2 vs. Ni after (Floyd *et al.*, 1989). GQ – the Goszów quartzites; MF – the Młynowiec Formation; SF– the Stronie Formation.

might be equivalents of the monotonous Młynowiec Formation cropping out in the eastern part of the OSD. This seems to be confirmed by the maximum sedimentation age for the Młynowiec metagreywackes which is 564.6 ±4.2 Ma (Mazur *et al.*, 2012). This age overlaps within an error with maximum deposition age for the Wyszki paragneiss. The Wyszki/Młynowiec metagreywackes collectively bear a resemblance to sediments of the external domain of the Saxo-Thuringian zone (the Rothstein formation).

In geochemical composition the rocks of the Młynowiec Formation (including Wyszki metagreywackies) show several features typical of sediments deposited in supra-subduction sedimentary basin. Diagrams based on immobile trace elements developed by Bhatia and Crook, (1986) show that all the analyses representing the Młynowiec Formation fall within the Continental Island Arc or Active Continental Margin fields (Fig. 2, Szczepański & Ilnicki, 2014). As suggested by TiO_2 and Ni relationship (Floyd *et al.*, 1989a) detritus filling this basin must have been supplied by erosion of evolved felsic igneous rocks (Szczepański & Ilnicki, 2014) (Fig. 2).

The geochemical similarity of the paragneisses of the Młynowiec Formation to sediments from the Saxothuringian Zone (Linnemann & Romer, 2002) suggests that a common tectonic setting may be key to explaining the origin of the Neoproterozoic to Cambrian volcano-sedimentary successions in the OSD and other fragments of the Cadomian orogen preserved in the European Variscan Belt. Following the model of (Linnemann, 2007), it may be hypothesized that deposition of the monotonous Młynowiec Formation preceded events related to the Cadomian orogeny and occurred in a back-arc setting during the time span preceding 540 Ma (Szczepański & Ilnicki, 2014).

Stop 1.4

Alternation of banded and streaky gneisses (Gierałtów type) with augen flaser gneiss (Śnieżnik type) – "transitional gneisses" in the Międzygórze Antiform

Leader: Aleksandra Redlińska-Marczyńska
Topic: Relationships of different types of gneisses: migmatization overprinted by mylonitization and deformation sequence
Location: N50°13'49" E16°45'32"; Baszta/Ambona Crag, ca. 600 m north from the centre of Międzygórze

A steep craggy cliff exposes two main types of gneisses characteristic of the Orlica–Śnieżnik Dome. In the eastern part of the Międzygórze Antiform, where the crag is, the gneisses intricately alternate and thus were once collectively referred to as transitional gneisses (Teisseyre, 1973). The two types differ in petrographic and textural characteristics, structural records, and rheology (see Żelaźniewicz *et al.*, 2014, this volume).

The Gierałtów type gneisses are realtively fine-grained and composed of Qtz+Pl+Kfs+Bt+Phg±Aln±Ttn±Grt±Ilm in varying proportions, especially in case of banded gneisses which consist of alternating, 1–50 cm thick bands of Bt-rich and Bt-poor domains. The modal proportion of alkali feldspar varies from 16% to 30% and of plagioclase [An_{6-38}] from 20% to 40%. A characteristic feature of these rocks is the presence of two sets of metamorphic foliations. In streaky gneisses, one is well marked by distributed yet parallel arrangement of mica flakes and irregularly spaced continuous to discontinuous quartzofeldspathic laminae, while the other, the earlier one, is involved in various, disharmonic to intrafolial folds (Fig. 1A, 2A). This is the oldest metamorphic plane S_1 (probably mainly mimetic to S_0) folded by F_2 folds with roughly subhorizontal N–S axes and the new axial planar foliation S_2. The most prominent feature of the D_2 event was a high temperature metamorphism that terminated with migmatisation. As a result, leucosome aggregates and segregations developed which together with K-feldspar porphyroblasts may have been conspicuously located in the hinge areas of F_2 folds. The structural control exerted by F_2 folds on feldspar blasts and quartzofeldspathic aggregates points to migmatization and blastesis that continued late- to post-kinematically with respect to D_2 deformation in the streaky, migmatitic gneisses. New aggregates and blasts continued to grow in random, which led to obliteration of earlier fabrics and imparted a granitic outlook to the rock.

The Śnieżnik type of gneisses consists an assemblage of Qtz+Kfs+Pl+Bt+Phg±Ap±Ttn±Grt, with characteristic flat modal distribution of alkalies (26–36% of alkali feldspar, 22–34% of plagioclase [An_{6-23}]). These are coarse- to even-grained metaigneous rocks that grade from porphyritic (meta)granite to flaser gneisses with genuine augen fabric (K-feldspar porphyroclasts) and one set of mylonitic layering/foliation (Fig. 1B).

In the exposure, the augen Śnieżnik gneiss together with its dynamically deformed flaser to layered variants alternate with the fine-grained banded and streaky gneisses

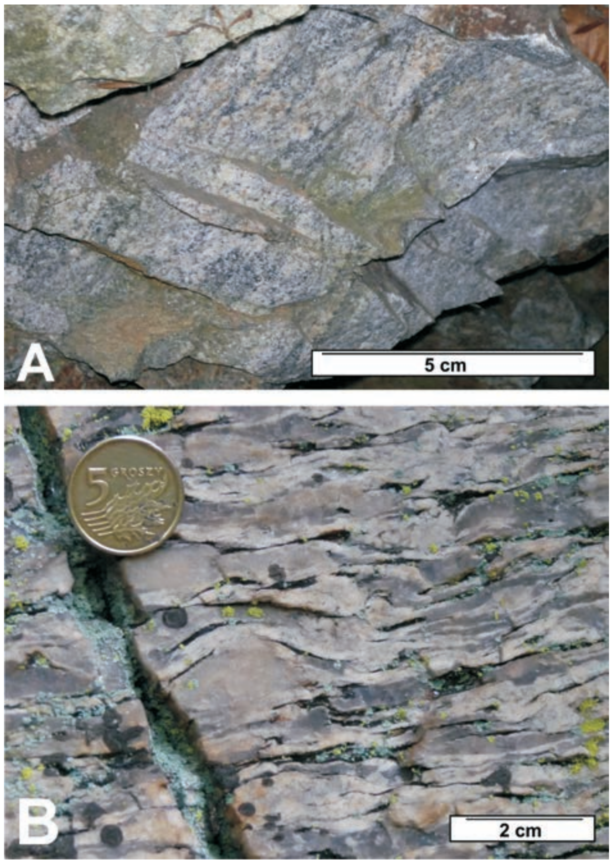

Fig. 1. Two types of gneisses in the Międzygórze Antiform. **A** – streaky migmatitic Gierałtów type gneiss, scale bar is 5 cm long; **B** – augen flaser Śnieznik type gneiss.

classified as the Gierałtów gneisses (Redlińska-Marczyńska & Żelaźniewicz, 2011; Redlińska-Marczyńska, 2014). All these rocks were later jointly subjected to shearing (stretching lineation – L_3) along the N(NW)–S(SE) direction, flattening (mylonitic foliation S_3), and large scale refolding F_4 (Fig. 2B). The shearing and mylonitization overprinted and partly obliterated earlier features of the streaky or migmatitic gneisses, which made them similar to coevally mylonitized Śnieżnik metagranite which locally enclosed these gneisses in form of the deformed enclaves. Detailed examination shows the differences.

The sequence of deformation recorded in the gneisses from the Ambona Crag indicates that HT metamorphism and migmatization in the Gierałtów gneisses preceded shearing and mylonitization. Further deformational stage (local D_3) brought about reactivation of the S_1–S_2 surfaces by shearing (S_1–S_2›S_3) with a roughly "top-to-the N" (locally top-to-the S and top-to-the NW) kinematics (Fig. 2) and overprint of the stretching lineation (N–NNW trending L_3). The rejuvenation of S_2 planes as S_3 planes led to deformation of earlier porphyroblasts and changed them into porphyroclasts (both delta and sigma types).

The next event (D_4) refolded earlier structures on the N–S trending axes which coincided with the earlier stretching lineation L_3 and produced E-vergent folds F_4 (z-type geometry) with flat-lying longer limbs, steep to overturned short limbs and weak to none axial plane growth (Fig. 2B).

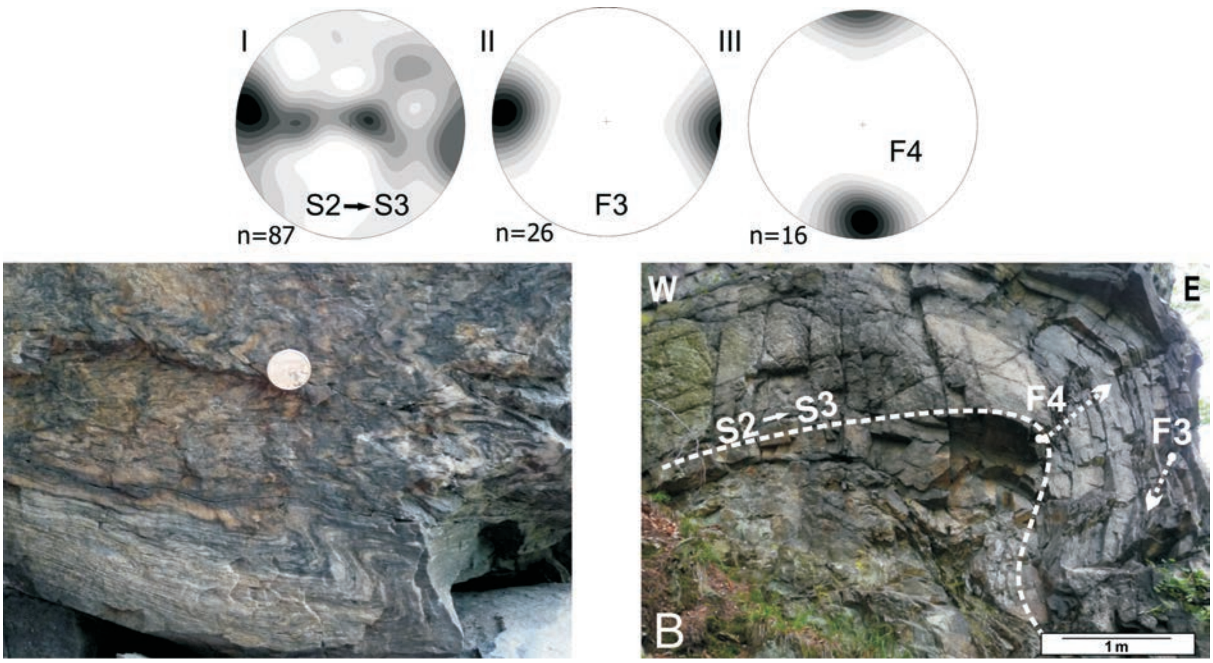

Fig. 2. Reconstructed sequence of deformation. **A** – F_2 folds with blasts in the hinge zones overprinted by N-vergent F_3 syn-shearing folds; **B** – z-type E-vergent folds F_4; I, II, III – contour diagrams to show orientation of structural features (lower hemisphere, equal area projection).

Where alternating augen flaser gneisses and streaky magmatic gneisses are involved in F_4 folds, differences in rheology between the type of gneisses may observed, in particular in the hinge zones.

The shearing and mylonitization D_3 and later E-vergent open folding D_4 are overprinted in the region gneisses that had different earlier fabrics: migmatitic in the Gierałtów gneisses and granitic in the Śnieżnik gneisses. This pattern is reproducible in all gneisses occurring in the Międzygórze Antiform. The structural records as presented in this exposure testifies that migmatization of the Gierałtów gneisses is older than mylonitization common throughout the Orlica–Śnieżnik Dome and that the migmatitic Gierałtów gneisses cannot be younger than shearing and transformation of the Śnieżnik granite into the Śnieżnik augen gneisses.

Stop 1.5

Light "Goszów" quartzites from the eastern limb of the Orlica–Śnieżnik Dome (Stara Morawa village)

Leaders: Mirosław Jastrzębski (ING PAN), Wojciech Stawikowski (UAM Poznań) & Bartosz Budzyń (ING PAN)
Topic: Tectonometamorphic record of the lowest part the Stronie Formation
Location: N 50°15'54'' E 16°52'29'', 200 to 300 m west of the lime kiln ("Galeria Wapiennik") in the village of Stara Morawa

Light quartzites of the Stronie Formation form a continuous marker 'horizon' ~15 meters thick and kilometres long, which separates other rocks of the Stronie Formation from paragneisses of the Młynowiec Formation and Śnieżnik orthogneisses (Don & Dowidar, 1988) (Fig. 1). Their stratigraphic and age relationships with respect to the adjacent mica schists of the Stronie Fm and paragneisses of the Młynowiec Formation are discussable (for review, see Żelaźniewicz *et al.*, 2014, this volume). The recent zircon studies indicate that the deposition of the Goszów quartzites protolith took place either during Middle Cambrian–Early Ordovician time span (Jastrzębski *et al.*, 2010) or during Early Ordovician (Mazur *et al.*, 2012).

The light quartzites are usually more resistant to weathering and erosion than adjacent rocks and outcrop in many localities. The visited exposure is situated in the village of Stara Morawa, where it forms an approximately 100 m wide, E–W oriented rock ridge. Three main petrographic varieties of light quartzites can be distinguished in this outcrop: (1) "pure quartzites" that are massive, fine-grained rocks mainly composed of quartz (80 vol%) and muscovite (up to 15 vol%), (2) "muscovite-rich quartzites" being transitional form to mica schists, characterized by alternating laminae of quartz (60–70 vol%) and phyllosilicates (Ms, Chl > Bt); the latter laminae commonly contain large (up to 7 mm) porphyroblasts of garnet, and (3) "K-feldspar quartzites" composed of quartz (80% vol%) and K-feldspar (~5% vol%). Two first varietes dominate in this outcrop and they form thin interlayers with interfingering contacts. K-feldspar quartzites are observed sporadically, with no sharp boundaries to the pure quartzites. The observed relationships between these varieties suggest that their protolith mainly comprised quartz sands frequently intercalated by more pelitic layers.

The penetrative features of these rocks is metamorphic foliation that dips toward N or NE at low to moderate angles and mineral lineation that plunges at low angles toward N. Meso-and microstructural observations indicate that this pe-

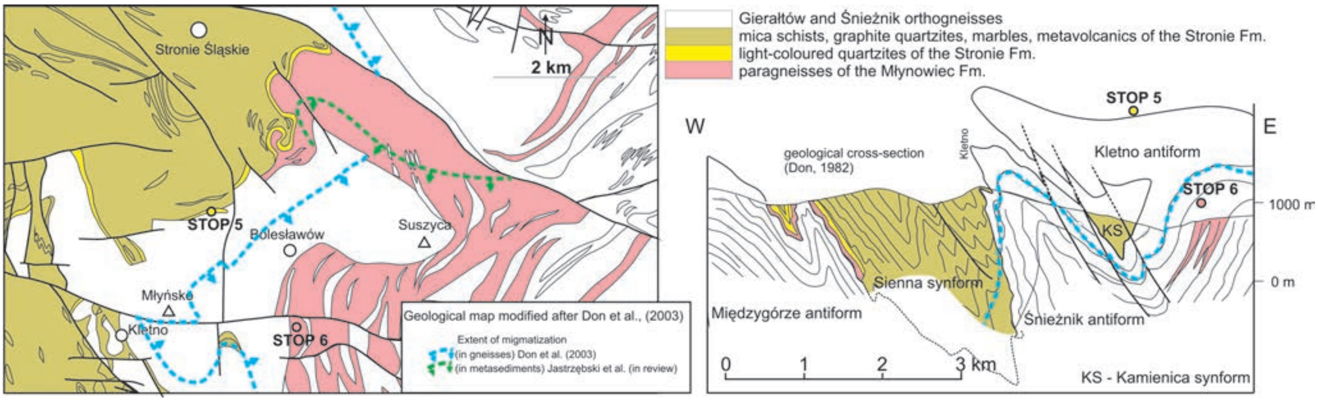

Fig. 1. Location of the stops 5 and 6 on geological map of Don et al. (2003) and cross-section of Don (1982).

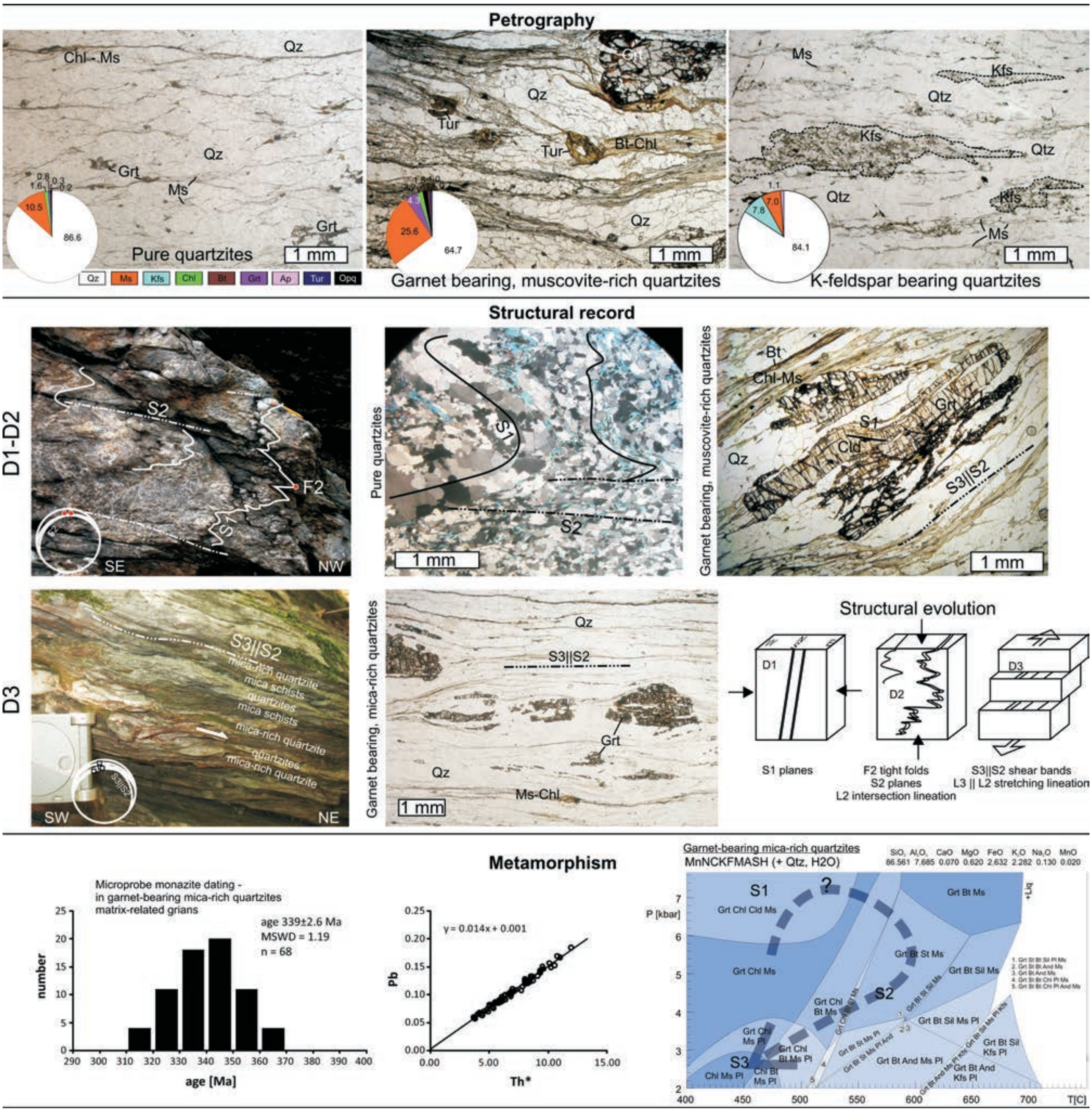

Fig. 2. Petrographic, deformation and metamorphic features of the light quartzites exposed in the village of Stara Morawa.

netrative foliation was developed as the axial planar to tight to isoclinal, N–S trending F_2 folds. The S2 planes are defined by quartz grain-shape fabric, sometimes emphasized by alternating laminae of quartz and phyllosilicates and parallel alignment of staurolite blasts. In "pure quartzites", relics of the S1 occur in form of folded quartz lamination. In the muscovite-rich quartzites, the S1 foliation is formed by the preferred orientation of chlorite-chloritoid-muscovite inclusion trails in garnet porphyroblasts. The S2 planes show a record of a reactivation as the S3 foliation resulted from the subsequent N–S directed ductile shearing and extension (Fig. 2). Shear sense indicators including σ-clasts indicate top-to-N movement along the S2 || S3 foliation. Syn-D2 fabric elements, i.e. garnet and staurolite grains have been stretched and boudinaged due to a progressive mylonitic deformation. This means that both the penetrative foliation and N–S trending lineation are polyphase structures developed during the D2 and D3 stages (Fig. 2). The D4 tectonic stage produced the concentric N–S (NE–SW) trending small-scale mesofolds F4.

Microstructures and pseudosection thermobarometry applied to garnet-bearing "muscovite-rich quartzite" indicates the temperature increase during development of the S2 foliation to the conditions of ca 580°C and 6 kbar. Changes in mineral assemblages related to the S1 and S2, and the obtained P-T path clearly correspond to those observed for the mica schists of the Stronie Formation from Krzyżnik Mt (Murtezi, 2006; Jastrzębski, 2009) that is located 1.2 km north of the visited outcrop. The D3 shearing was connected with the conditions at which biotite was replaced by chlorite and garnet was not stable (below 450°C, and 3 kbar).

The detailed electron microprobe monazite dating has been performed on the single sample. Concentrations of U, Th and Pb in all studied monazites, recalculated using age equations from Montel et al. (1996), yielded U-Th-total Pb age of 339 ± 2.6 Ma (MSWD: 1.19, n=68). They provide a wide range of ages, between 310 and 370 Ma, suggesting prolonged metamorphic processes experienced by the quartzites. The highest concentration (more than a half of results) falls between 330 and 350 Ma, indicating the period of most pronounced monazite growth. All the studied monazites were matrix-related. Therefore the obtained maximum in ~340 Ma can be either related to the D2 or to the D3 tectonic event recorded by these rocks.

Stop 1.6

Migmatized Młynowiec paragneisses from Zawada Mt. (near Bolesławów village)

Leaders: Mirosław Jastrzębski (ING PAN), Wojciech Stawikowski (UAM Poznań) & Bartosz Budzyń (ING PAN)
Topic: Local migmatization of the Młynowiec–Stronie Group
Location: N 50°14'54", E 16°50'38", northern ridge of the Zawada Mountain

The presence of local migmatization of the Młynowiec Formation paragneisses in the Orlica–Śnieżnik Dome was signalled by Don et al. (2003). These authors delineated an extent of migmatization in the supracrustal rocks on their map of the Lądek–Śnieżnik Metamorphic Unit. The migmatized paragneisses form a ~100 meters long and several meters high exposure at the northern ridge of Zawada Mountain, to the south of Bolesławów village.

In contrast to typical paragneisses and mica schists of the Młynowiec formation, the rocks from Zawada contain numerous pods and patches of leucocratic material (composed mainly of plagioclase and quartz, with up to 2 mm garnets and subordinate micas). Mesosome is a medium-grained paragneiss containing quartz, plagioclase, muscovite and biotite, garnet as well as sillimanite visible at the microscopic scale. Leucosome patches display more weakly oriented fabric and larger grain size compared to the surrounding mesosome. Occasionally, they show pegmatoid texture. The leucosome bodies form either small patches (1– 2 cm), dispersed within the mesosome, or elongated pods up to 20 cm thick and more the meter long. The relationships between the leucosome and the mesosome indicate in-situ migmatization, with only local transport of the metatectic material.

The conspicuous foliation in the migmatized paragneisses dips W to WNW under moderate to steep angles, and contains subhorizontal lineation plunging towards N–NNW. This planar feature was developed as the axial planar foliation (S2) of tight to isoclinal N–S trending folds (F2). Asymmetrically deformed leucosome patches together with the C' surfaces predominantly indicate top-to-the S/SSE shearing (S3), in contrast to top-to-the-N kinematics of the S3 planes in the previously visited outcrop (stop 5). Also the mineral lineation displays stretching character (defined by elongated leucocratic patches), confirming the presence of shearing event registered by the paragneisses (Fig. 1).

The pseudosection coupled with contouring of the mineral composition isopleths, show that the syn-D2 mineral assemblage Qz–Pl–Ms–Bi–Grt–Sil–Liq developed at ~700 °C and 6 kbar. The contouring of both the prograde part of the P–T loop and of the P–T values obtained for the peak temperature assemblage, indicates that the D2 event was followed by the pressure peak (Fig. 1).

The N-dipping S2 foliation in the rocks near Stara Morawa and the W-dipping S2 foliation in the rocks near Bolesławów form the two limbs of the large-scale, overturned fold (fan-like Kletno fold according to the nomenclature of Don, 2001). This also results in the observed opposite shear senses in its opposite limbs. Similarly, the differences in the observed P-T conditions between rocks of the Stronie Formation and the migmatized part of the Młynowiec Formation are plausibly explained by late regional folding, which led to the deformation and tilting of both the lithological contacts, the S2 planes as well as the Barrovian metamorphic isotherms (see Fig. 1 for stop 5) (Jastrzębski *et al.* 2014, *in review*).

The geochronological study of monazites and zircons from the migmatized paragneisses was performed. Monazites occur in the rock matrix, both of the leucosome and the mesosome. The Th-U-total Pb dating of the leucosome monazites yielded an age of 337 ± 3 Ma, while monazites from the mesosome gave 331 ± 6 Ma, with the faint record of 355

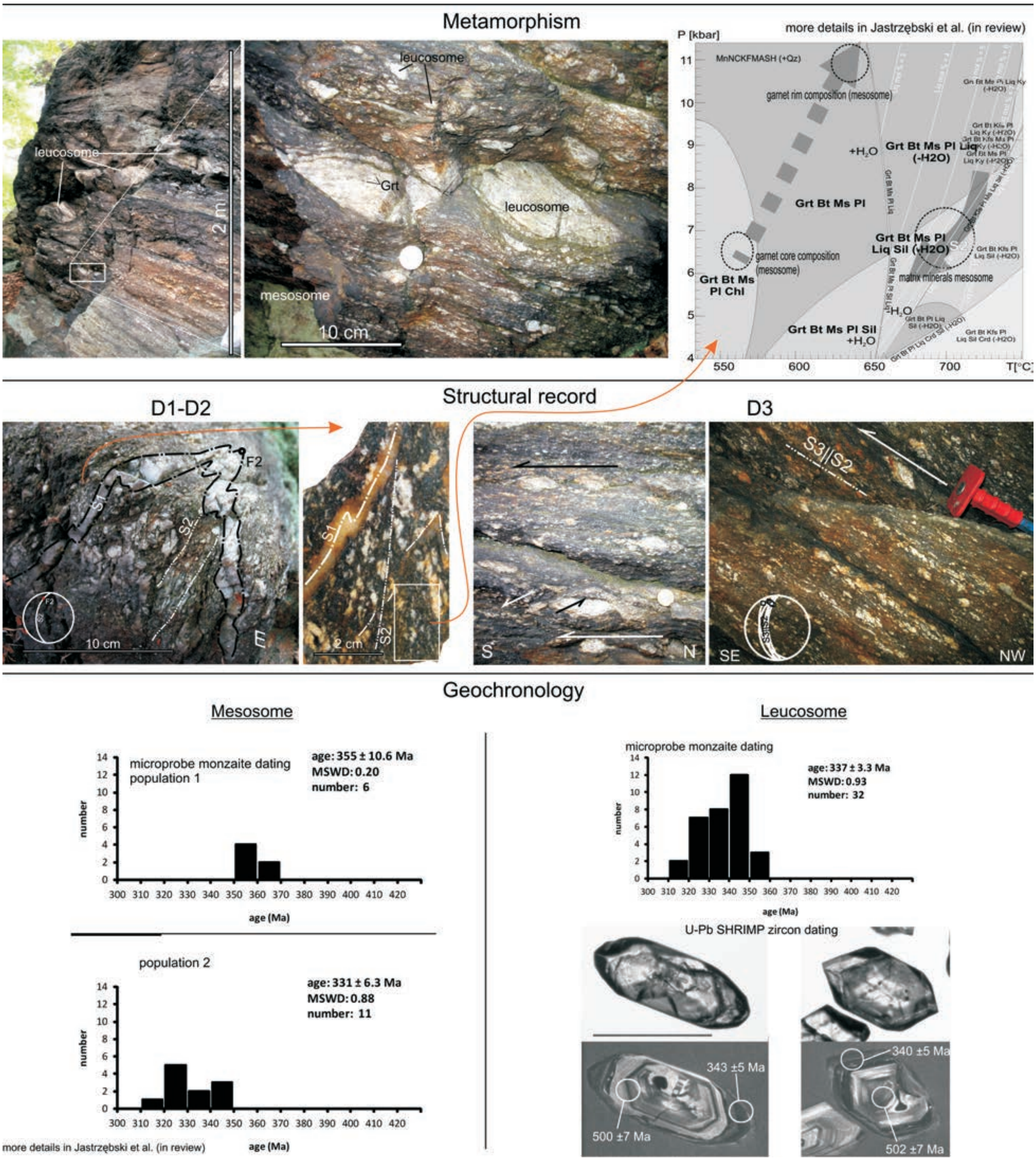

Fig. 1. Petrographic, deformational and metamorphic features of the migmatic rocks exposed at the Zawada Mt.

± 11 Ma age. The above-mentioned 330–340 Ma monazite ages from the leucosome patch, can be interpreted as constraining the time of local migmatization of the Młynowiec Formation.

The collected larger, pegmatoid-like leucosome body is reach in semitransparent, rarely clear, normal-prismatic zircon crystals. These zircons are 100 to 250 µm long, subhedral to euhedral. Almost the whole zircon population reveals clear small-scale oscillatory zoning. Most of the crystals have up to 40 µm wide rims, darker in cathodoluminescence. The U-Pb SHRIMP zircon study yielded ages concentrated in two groups. The first group, referring to the oscillatory-zoned parts of the zircon grains, includes the results ca. 500 Ma. The second one, obtained for rims of the zircon prisms, yielded ages of ca. 340 Ma. Such a dispersal of the results can be interpreted in two alternative ways. The first explanation states that the ~340 Ma age represents the migmatization event, while the oscillatory-zoned inner parts of the zircons are inherited. The strongly concentrated ~500 Ma age cluster is, however, in contradiction with the wide scatter of zircon ages expected in case of (meta)detrital origin, presumed for the visited rocks. According to the second explanation, ca. 500 Ma ages could be interpreted as the age of migmatization of the Młynowiec paragneisses, while the age of ~340 Ma (commonly registered in the OSD) would record the Variscan thermal overprint. The data obtained from the monazite dating support the first interpretation. Nevertheless, additional dating of zircons coming from the mesosome is necessary to evaluate the meaning of the obtained geochronological results and to shed more light on the protolith of the sheared migmatic rocks from the Zawada Mt.

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