GEOLOGIA SUDETICA, VOL. 27, 1 - 2, 1993, 21 - 64

Marian DUMICZ[1]

THE HISTORY OF ECLOGITES IN THE GEOLOGICAL EVOLUTION OF THE ŚNIEŻNIK CRYSTALLINE COMPLEX BASED ON MESOSTRUCTURAL ANALYSIS[2]

Historia eklogitów w ewolucji metamorfiku Śnieżnika w świetle analizy mezostrukturalnej[3]

Abstract. The results of mesostructural analysis are presented in relation to the tectonics of the Śnieżnik massif. The most part of observations concerning the sequence and development mechanisms of the successive generations of minor structures was made in the gneissic series. Particularly interesting were phenomena recording the successive stages of transformation of the S_1 lamination into S_3 lamination. On the basis of field observations and an analysis of mesostructures using stereograms, prepared separately for the gneissic series and for the eclogites, an attempt was made to relate the tectonic structures found in these rocks to four deformation events D_1 to D_4, probably common to both series. The results show that both series responded differently to tectonometamorphic processes, which was best reflected by the effects of the third deformation event D_3. Not enough information has been gathered so far to make possible a detailed comparison of the effects of the D_1 and D_2 deformations in the gneisses and the eclogites. It may only be suggested that the protolith of the eclogites was emplaces into the gneisses prior to the D_2 deformation. In the case of eclogites alternating with granulites of the Stary Gierałtów, the performed analysis reveals a perfect accordance of the structural development of both rock varieties. The effects of the D_1 to D_4 deformation events detected in these rocks can be easily compared with their age equivalents in the Gierałtów gneisses. Moreover, observations are presented that may suggest that the garnet and omphacite blastesis in the granulites occurred before the development of the S_3 gneissosity and L_3 lineation. The sequence of tectonometamorphic phenomena is discussed as well, within the framework of the geodynamic model of the Śnieżnik massif proposed by Borkowska *et al.* (1990).

---

1 Institute of Geological Sciences, Wroclaw University, Cybulskiego 30, 50-205 Wroclaw, Poland.

2 Manuscript received 20 June 1991, accepted 16 March 1992.
3 Wpłynęło 20 czerwca 1991, przyjęto do druku 16 marca 1992.

Key words: Mesostructures, eclogites, Variscan metamorphism, Śnieżnik massif, Sudetes, Poland.

Abstrakt. Na tle szkicowo zarysowanego planu tektonicznego metamorfiku Śnieżnika przedstawiono rezultaty analizy mezostrukturalnej. Najwięcej informacji o następstwie i mechaniźmie rozwoju poszczególnych generacji drobnych struktur dostarczyła seria gnejsowa. Interesujące okazały się tutaj zwłaszcza zjawiska rejestrujące poszczególne fazy przekształceń laminacji S_1 w laminację S_3. Opierając się na obserwacjach terenowych i na analizie obrazu rozmieszczenia mezostruktur na diagramach, oddzielnie przeprowadzonych dla serii gnejsowej i dla eklogitów, podjęto próbę powiązania stwierdzonych w tych skałach struktur tektonicznych z czterema, jak się wydaje, wspólnymi dla nich etapami deformacji D_1-D_4. Wyniki jej wskazują, że skały te reagowały różnie na procesy tektonometamorficzne, co uwidoczniło się najlepiej w efektach trzeciego aktu deformacji D_3. Dotychczas nie zebrano odpowiedniej ilości informacji do szczegółowego porównania efektów deformacji D_1 i D_2 w serii gnejsowej i w eklogitach. Można jedynie przyjąć z dużym prawdopodobieństwem, że protolit występujących tu eklogitów pojawił się w serii gnejsowej przed deformacją D_2. W przypadku eklogitów występujących w przeławiceniach z granulitami serii Starego Gierałtowa przeprowadzona analiza wskazuje na całkowitą zgodność rozwoju strukturalnego tych odmian skalnych, a prześledzone w nich efekty deformacji D_1-D_4 dają się łatwo porównać z ich analogami wiekowymi w gnejsach gierałtowskich. Ponadto przedstawiono obserwacje mogące sugerować, że blasteza granatów i omfacytu, czyli eklogitowy metamorfizm, w serii granulitowej nastąpiła po uformowaniu fałdów F_2, a przed powstaniem zgnejsowania S_3 i lineacji L_3. Omówiono rówież następstwo zjawisk tektonometamorficznych na tle modelu geodynamicznego rozwoju metamorfiku Śnieżnika autorstwa Borkowskiej *et al.* (1990) i danych radiometrycznych Bakun-Czubarow i Bruecknera (1991), których jednoznaczna interpretacja nastręcza poważne trudności.

CONTENTS

INTRODUCTION

The history of eclogites in the geological evolution of the Śnieżnik crystalline complex has focused attention of the Warsaw school petrologists from the very beginning of their research in that region. In the 1960's several comprehensive papers were published which dealt with this problem. These were the articles by Smulikowski (1963, 1964, 1967), Kozłowski (1965) and Bakun-Czubarow (1968). These authors put forward several arguments supporting the view on the genetical relation of the eclogites with the Stronie series. Smulikowski (1957) ascribed the origin of the Gierałtów and Śnieżnik gneisses of granite composition to the Stronie series, regarding them as coeval and differing only in the degree of advancement of their metamorphic evolution (higher in the case of the Śnieżnik gneisses).

Geologists joined the discussion of this problem relatively late. At the end of the 1980's Don (1989) put forward an interesting concept, that the eclogites of the Śnieżnik massif were exotic bodies transported from the deep substratum. They might have travelled a long distance, from a subduction zone, together with the young Caledonian Gierałtów gneisses, which formed in the same zone. The Gierałtów gneisses pierced through, often as diapires, to the higher hypsometric levels of the Stronie series and the Śnieżnik gneiss of granite composition.

The present paper sums up the research work, carried out since 1988, concerning the relation of the granulites and eclogites to the gneisses of the Snieżnik complex.

MESOSTRUCTURAL CHARACTERISTICS OF THE GNEISSIC SERIES

Mesostructural studies aimed at exploration of mutual age relations between the Gierałtów gneisses and the Śnieżnik gneisses are almost over. Their results are in part already published (Dumicz 1988, 1989a, 1989b, 1990 – in Don *et al.*). They revealed many facts which might help in better understanding of the role played by the eclogites in the geological evolution of the Śnieżnik massif, since most of these rocks occur within the Gierałtów gneisses. The work has been carried out during the last three years, and author's investigations have been extended onto eclogites in the granulitic series and the Stronie series (Fig. 1).

In 1988 mesostructural analysis of eclogites and the surrounding rocks in Międzygórze was performed. The results were presented in the papers of the field conference held in Międzygórze on 11 and 12 September 1989, and in another short paper (Dumicz 1991).

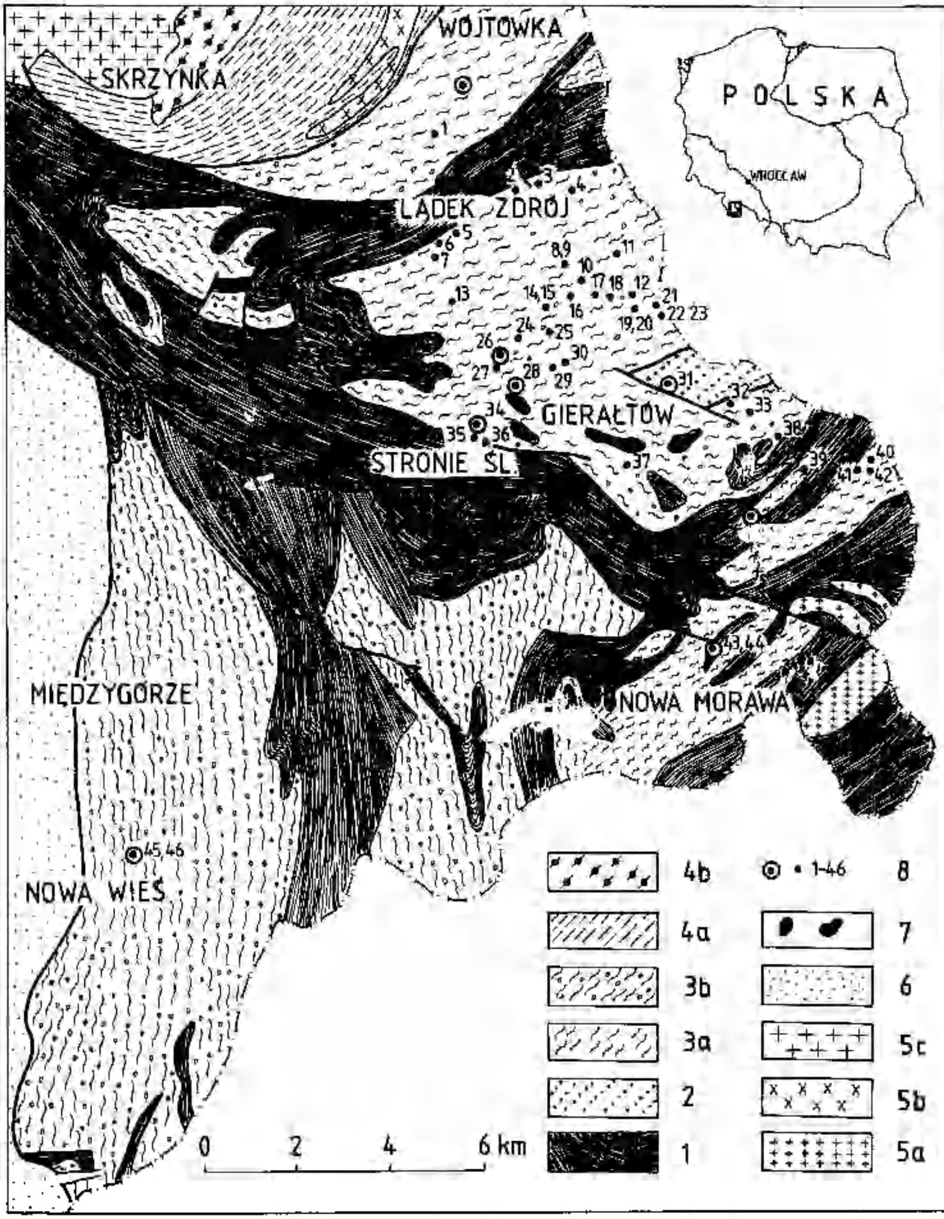


Fig. 1. Geological sketch of the Śnieżnik massif after Don (1964) with modifications of Smulikowski (1979). *1* – Stronie Series (undifferentiated); *2* – granulitic Series; *3a* – granite gneisses of Gierałtów type; *3b* – granite gneisses of Śnieżnik type; *4a* – blastomylonites and blastocataclasites; *4b* – gneisses of Haniak type; *5a* – Bielice granitoids; *5b* – Jawornik granitoids; *5c* – Kłodzko-Złoty Stok granitoids; *6* – upper Cretaceous; *7* – Cainozoic basaltoids; *8* – observation localities: *dots* – gneisses, *encircled dots* – eclogites, numbers refer to diagrams of Fig. 2

In 1989 and 1990 the remaining outcrops of eclogites and accompanying rocks were studied structurally in the following places: Wójtówka, Strachocin near Stronie Śląskie, Stary Gierałtów, Czernica, Nowa Morawa and Nowa Wieś (Fig. 1, observation points 1 to 46). The stereograms shown in Fig. 2 were numbered in the same way (1 to

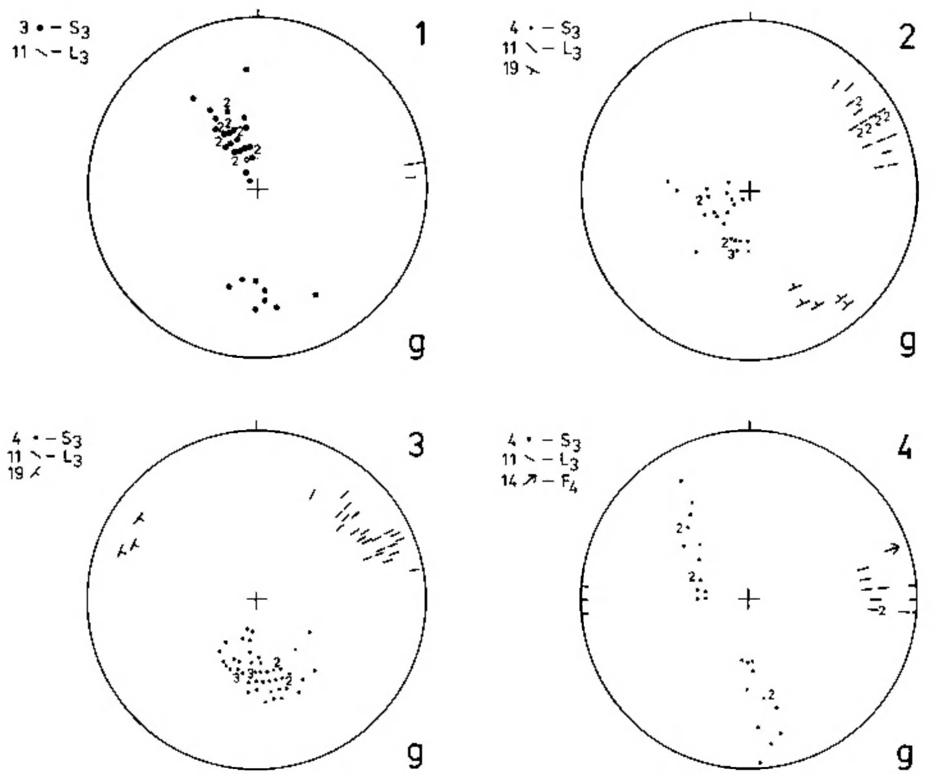
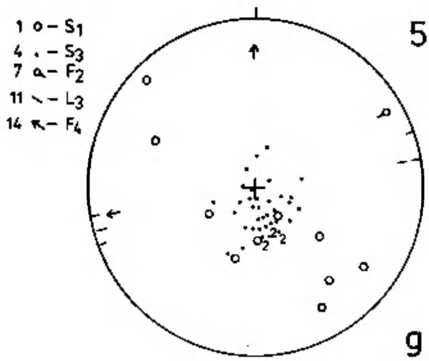
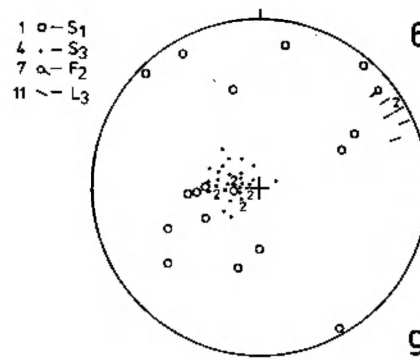
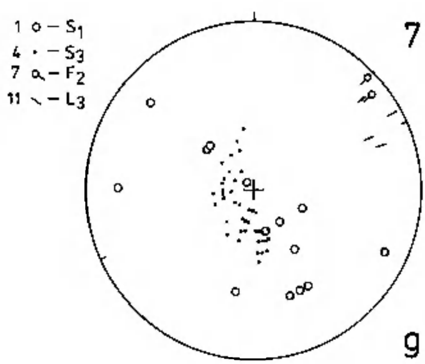
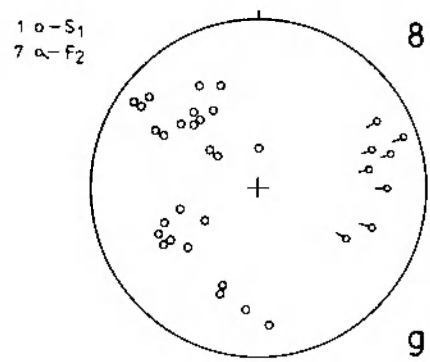


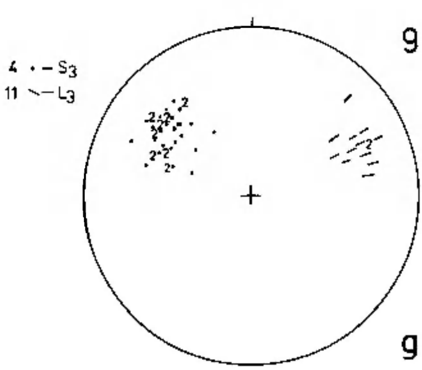
Fig. 2. Stereograms (1 - 46) of mesostructures in the gneisses (*g*) and eclogites (*e*) (lower hemisphere). Poles to planar structures: *1* – S_1 lamination in the Gierałtów gneisses; *2* – S_1 lamination in eclogites and amphibolites; *3* – $S_{3(2+3)}$ lamination in the Gierałtów gneisses; *4* – S_3 gneissosity in the Śnieżnik gneisses and the Gierałtów gneisses; *5* – S_3 cleavage in eclogites and amphibolites; *6* – S_4 crenulation cleavage in the Gierałtów gneisses. Folds and linear structures: *7* – F_2 fold axes in the Gierałtów gneisses; *8* – F_2 fold axes in eclogites and amphibolites; *9* – F_3 fold axes in the Gierałtów gneisses; *10* – F_3 fold axes in the eclogites and amphibolites; *11* – L_3 lineation in the Gierałtów gneisses and the Śnieżnik gneisses; *12* – L_3 lineation in eclogites and amphibolites; *13* – L_4 lineation in the Gierałtów and the Śnieżnik gneisses; *14* – F_4 fold axes in the Gierałtów and the Śnieżnik gneisses; *15* – F_4 fold axes in the Gierałtów and the Śnieżnik gneisses with indicated (structure) asymmetry; *16* – F_4 fold axes in eclogites and amphibolites; *17* – axes of folds of unidentified generation. Other: *18* – poles to joints healed with dark material in eclogites; *19* – envelopes of F_3 folds formed due to deformation of S_1 lamination in the Gierałtów gneisses; *g* – stereograms referring to gneissic series; *e* – stereograms referring to eclogites and amphibolites

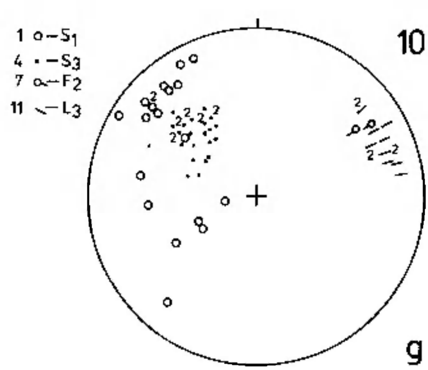

5
1 o – S1
4 . – S3
7 – F2
11 – L3
14 – F4
g

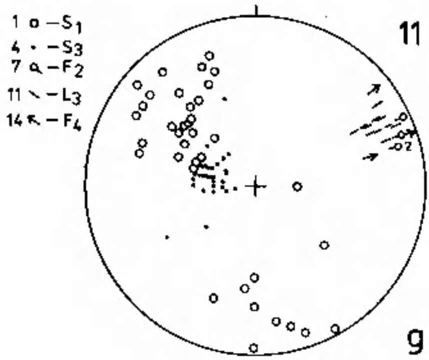

6
1 o – S1
4 . – S3
7 – F2
11 – L3
g

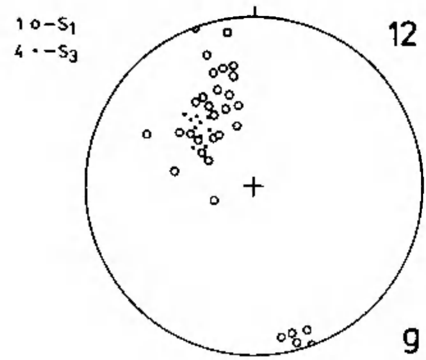

7
1 o – S1
4 . – S3
7 – F2
11 – L3
g

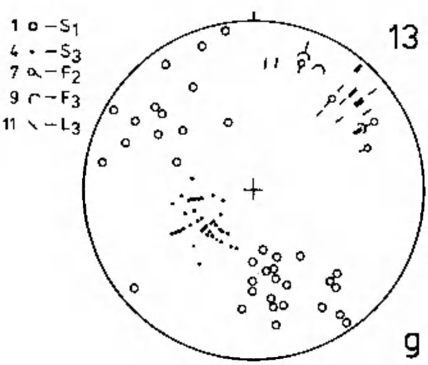

8
1 o – S1
7 – F2
g

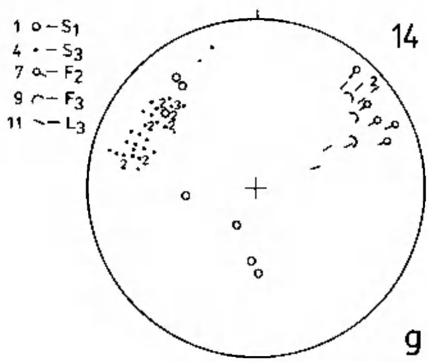

9
4 . – S3
11 – L3
g

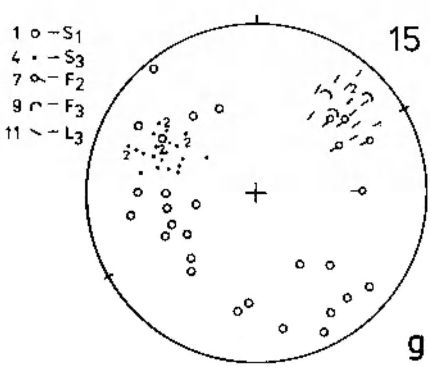

10
1 o – S1
4 . – S3
7 – F2
11 – L3
g

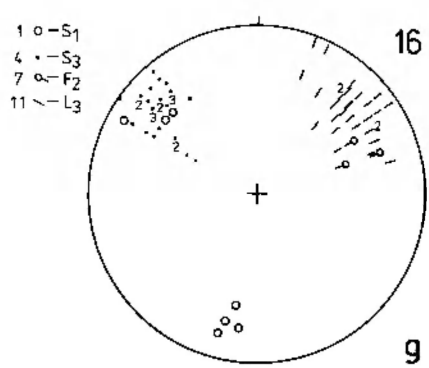

1 o – S1
4 • – S3
7 – F2
11 – L3
14 – F4
11
g

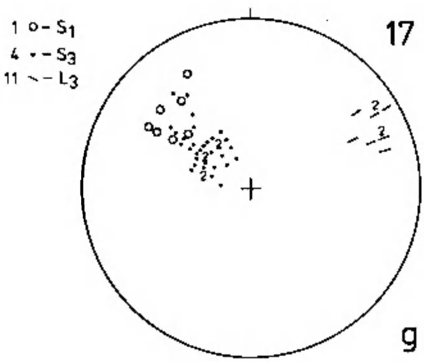

1 o – S1
4 • – S3
12
g


1 o – S1
4 • – S3
7 – F2
9 – F3
11 – L3
13
g

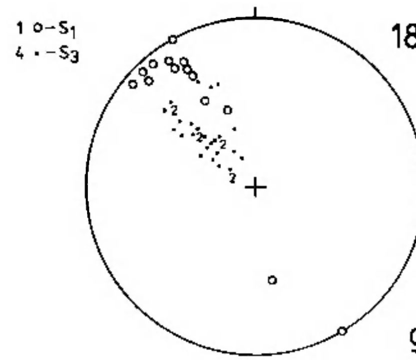

1 o – S1
4 • – S3
7 – F2
9 – F3
11 – L3
14
g


1 o – S1
4 • – S3
7 – F2
9 – F3
11 – L3
15
g

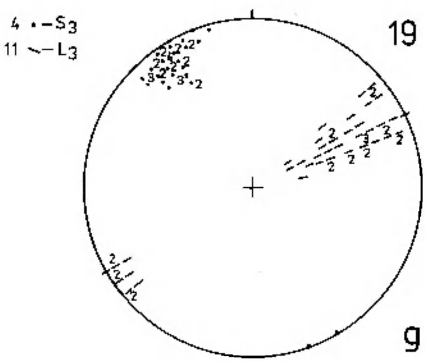

1 o – S1
4 • – S3
7 – F2
11 – L3
16
g



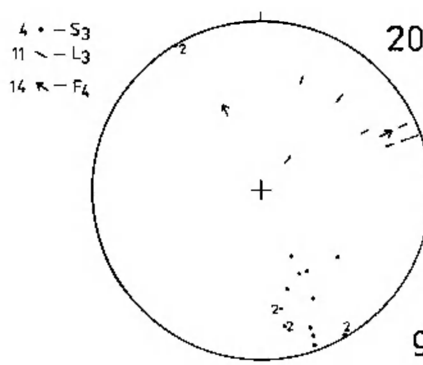
17



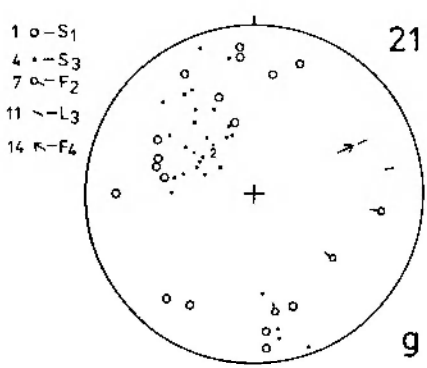
18



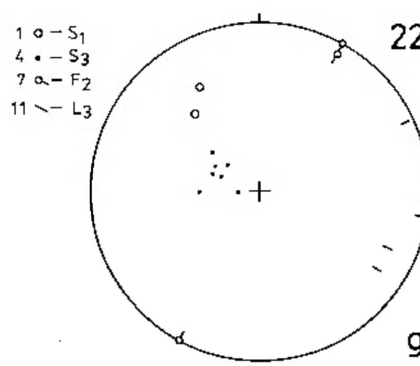
19



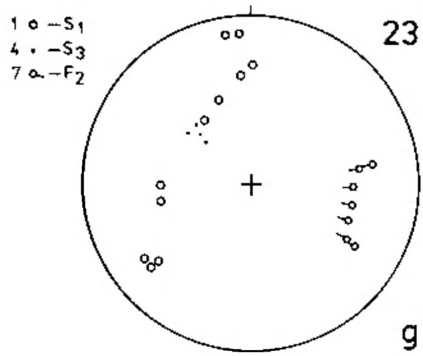
20

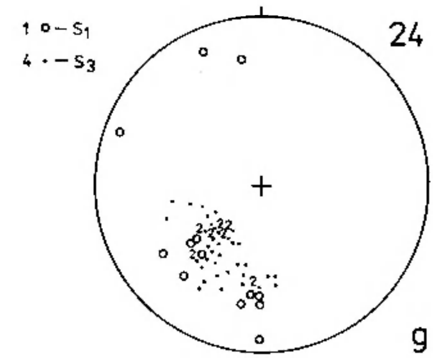


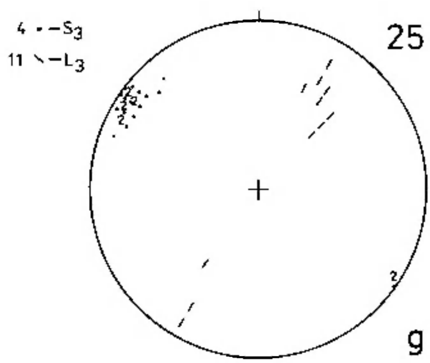
21

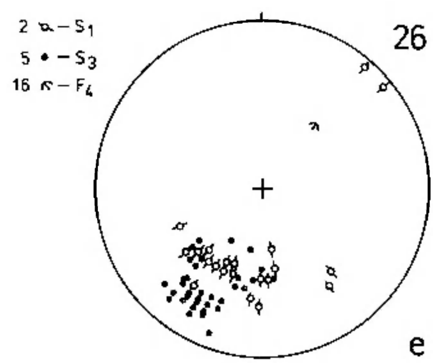


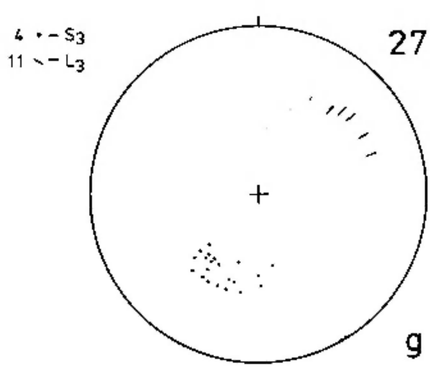
22

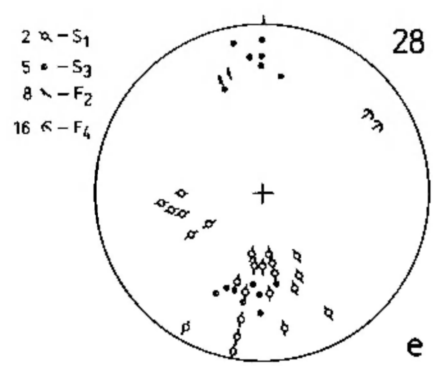

1 – S_1
4 – S_3
7 – F_2
23
g

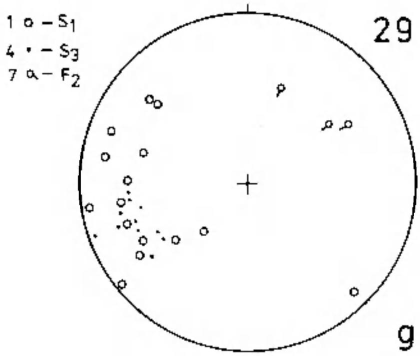

1 – S_1
4 – S_3
24
g

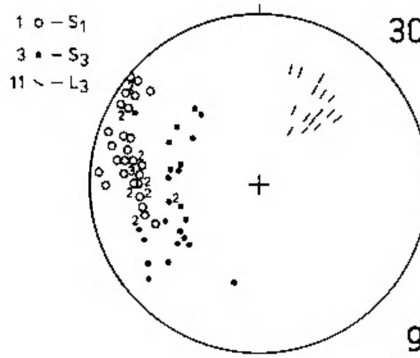

4 – S_3
11 – L_3
25
g

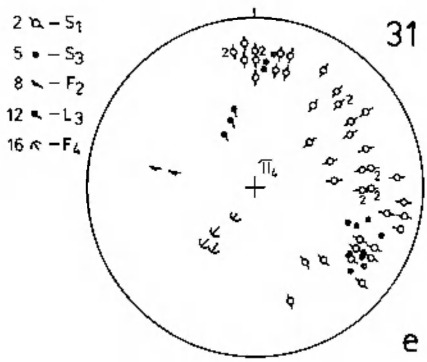

2 – S_1
5 – S_3
16 – F_4
26
e

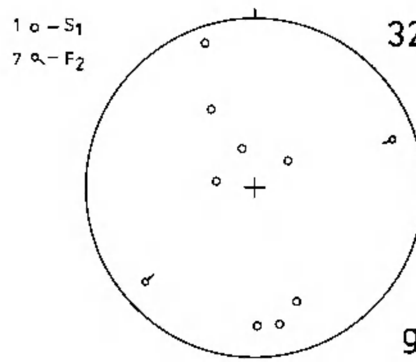

4 – S_3
11 – L_3
27
g

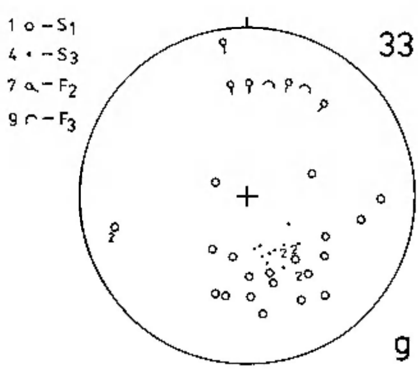

2 – S_1
5 – S_3
8 – F_2
16 – F_4
28
e

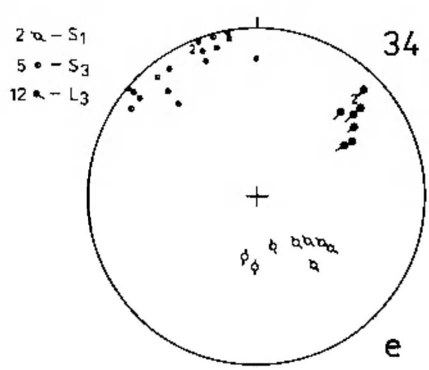

1 o – S1
4 • – S3
7 – F2
29
g

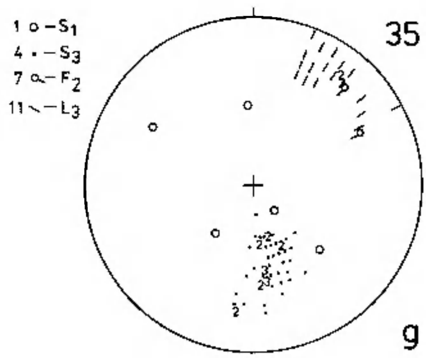

1 o – S1
3 • – S3
11 – L3
30
g

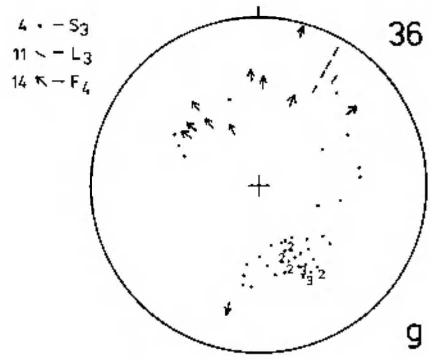

2 – S1
5 • – S3
8 – F2
12 – L3
16 – F4
31
π4
e

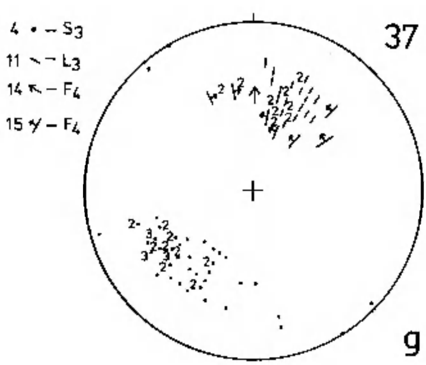

1 o – S1
7 – F2
32
g

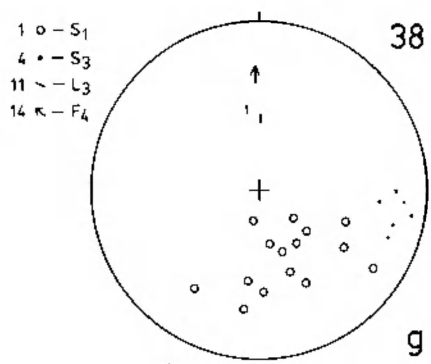

1 o – S1
4 • – S3
7 – F2
9 – F3
33
g

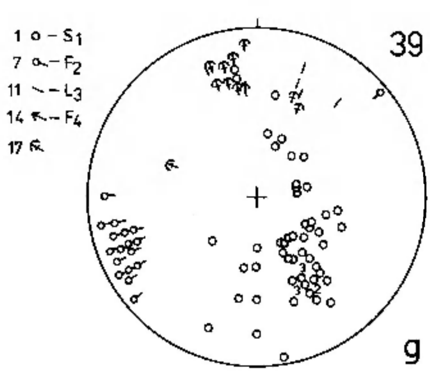

2 – S1
5 • – S3
12 – L3
34
e

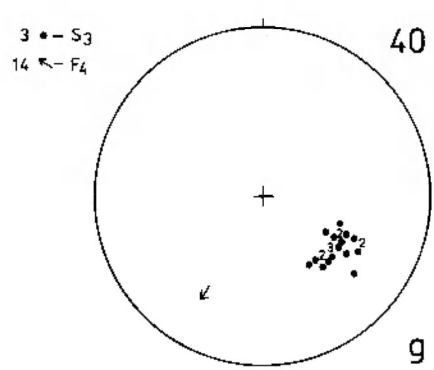

1 – S_1
4 – S_3
7 – F_2
11 – L_3
35
g

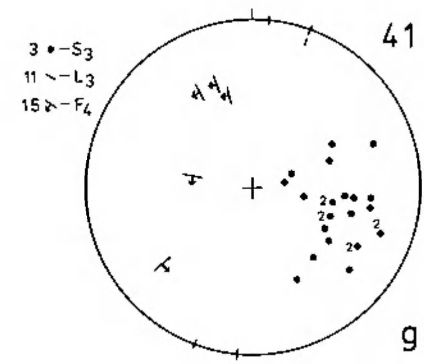

4 – S_3
11 – L_3
14 – F_4
36
g

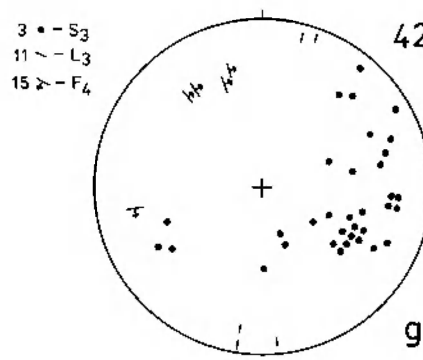

4 – S_3
11 – L_3
14 – F_4
15 – F_4
37
g

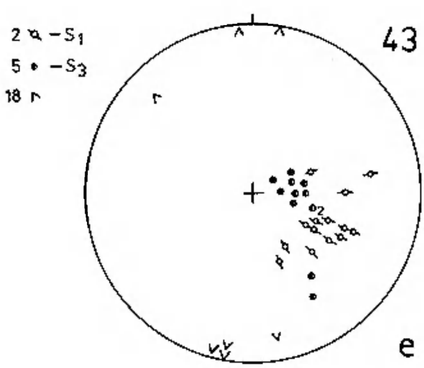

1 – S_1
4 – S_3
11 – L_3
14 – F_4
38
g

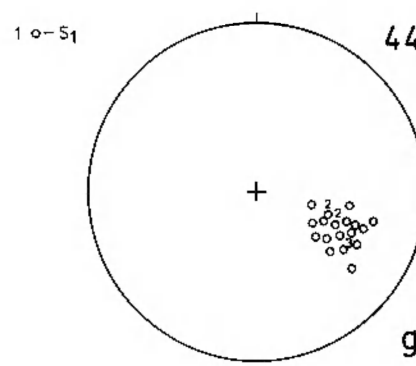

1 – S_1
7 – F_2
11 – L_3
14 – F_4
17
39
g

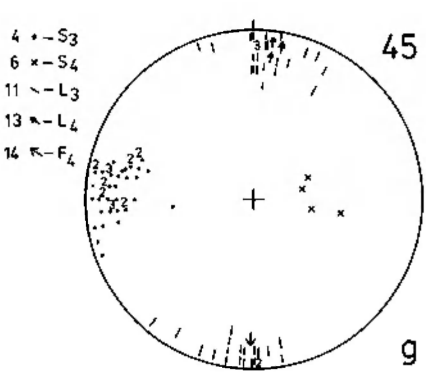

3 – S_3
14 – F_4
40
g

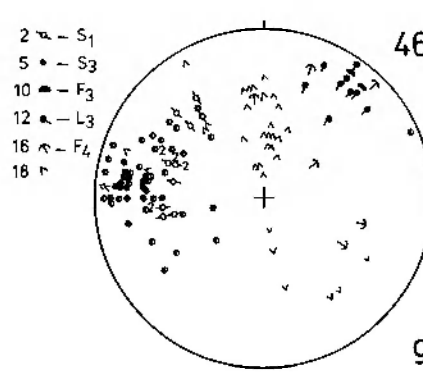

41
3 • – S3
11 ∼ – L3
15 – F4
g


42
3 • – S3
11 ∼ – L3
15 – F4
g


43
2 – S1
5 • – S3
18
e


44
1 o – S1
g


45
4 • – S3
6 × – S4
11 ∼ – L3
13 – L4
14 – F4
g


46
2 – S1
5 • – S3
10 – F3
12 – L3
16 – F4
18
g

46) as the corresponding observation points on the map (Fig. 1). These investigations permitted distinguishing S_1 metamorphic lamination within the Gierałtów gneisses and the so called transition gneisses. This S_1 lamination in the gneisses is an equivalent of S_1 lamination in paragneisses of the Stronie series, into which the Gierałtów gneisses gradually pass, as pointed out by Smulikowski (1957), Oberc (1957) and Teisseyre (1957) already in the 1950's. The S_1 lamination is intensively deformed by penetrative, morphologically, regionally varied F_2 folds (Pl. I, *1, 2*).

The other phenomena observed in the gneissic series are, first of all, S_3 planar structures. They are superimposed, in places concordantly, in places discordantly, onto axial planes of the F_2 folds and occur in various forms in the Gierałtów gneisses:

– sometimes they show features typical of schistosity or gneissosity, making the rock appearance similar to that of the Śnieżnik gneiss,

– some other times they manifest themselves as zones of tectonic transposition (Pl. II, *1, 2, 3*), to which the older structural elements (in this case S_1) adjust.

Deformation partitioning, as defined by Bell *et al.* (1986), occurs here, consisting in alternation of zones in which buckling was the main deformational mechanism and zones where shearing predominated. Advancing tectonometamorphic processes led in these zones to a widespread, synkinematic, directional recrystallization and to formation of a new lamination, S_3 (Pl. III, *1* left side), typical of the metamorphically rejuvenated variety of the Gierałtów gneisses.

These processes were particularly intensive in the tectonic zone of Skrzynka-Złoty Stok, where their petrographic aspect was most profoundly studied by Burchart (1960), Smulikowski (1973, 1976) and Kozłowska-Koch (1973).

The S_3 gneissosity in the Śnieżnik gneisses is connected with the same period of time (Pl. III, *2*). S_3 is the oldest directional structure in the typical, i.e. augen and laminated-augen varieties of these rocks. This suggests that before acquiring the S_3 gneissosity these rocks were isotropic, probably granitic material.

Mesostructures related to the fourth event of tectonic deformation correspond, first of all, to folds affecting the S_3 lamination and gneissosity. They are mostly concentric folds, rarely boudins and only locally deformations associated with mesoscopically visible component of shearing and recrystallization, as exemplified in an outcrop of gneisses near Karpno (Pl. IV, *1, 2*). The F_4 folds occurring in this outcrop are distinctly asymmetric. Their longer limbs are thinner than the shorter ones and have different internal structure. In the longer limbs it is fine lenticular-lamination that predominates, whereas in the shorter limbs the dominant structure is coarse rodding-lamination. It is the result of axial plane shearing taking place along surfaces orientated obliquely (at a small angle) to the longer limbs and steeply (at a high angle) to the shorter limbs of the F_4 folds. This structural diversification within the rocks occurs parallel to axial planes of the F_4 folds and must have formed simultaneously with the formation of these folds.

As regards the linear structures in the Gierałtów gneisses and the so called transition gneisses, the L_3 lamination is predominant. In most cases it is an intersection lineation formed due to cross-cutting of the S_1 lamination by S_3 schistosity (Pl. IV, *3*), and hence strong variations in its orientation occur, being usually visible already on the scale of an outcrop (Pl. V, *1*) or a hand specimen (Pl. V, *2*). Variable are also forms of L_3 lineation, sometimes related to different stages of evolution. It was noticed that fine rodding structures – $L_3(S_1/S_2)$ – change their shapes from an irregular oval to a thinner, lenticular one, finally becoming the S_3 lamination (Dumicz 1989a, Pl. XI), typical of the metamorphically rejuvenated Gierałtów gneisses. This whole sequence resulted from progressive deformation.

In the typical variety of the Śnieżnik gneisses, i.e. augen and lamination-augen variety, the L_3 lineation appears mostly as elongated shapes of augens and quartz-feldspar lenses (Dumicz 1989a, Pl. I). It has not been explained as yet to what extent these structures are the result of stretching and to what extent of rotation.

The stereograms presented in this paper (Fig. 2) reflect complex spatial relations between individual types of structures in question. Pictures of their distribution on stereograms are highly variable; nevertheless it was possible to notice some regularities valid for the whole area of study:

– the S_1 lamination, preserved as relics, reveals high, irregular distribution while the S_3 gneissosity, cutting across the S_1, retains constant position on the scale of an outcrop or is distributed in a spatially regular manner;

– the F_4 folds, formed through deformation of the S_3 lamination and gneissosity, are usually cylindrical folds, and only sporadically non-cylindrical, conical ones (Fig. 2, diagrams 30 and 31);

– the strong dispersion of the L_3 lineation results most often from its intersection character, i.e. from superposition of the S_3 gneissosity and S_3 lamination of relatively constant position on variably orientated S_1 lamination.

STRUCTURAL POSITION OF ECLOGITES IN THE ŚNIEŻNIK CRYSTALLINE COMPLEX

The above presented outline of the mesostructural evolution of the gneissic series of the Śnieżnik crystalline complex will serve us as the background for a discussion on the history of eclogites in the evolution of the Śnieżnik complex.

What rock varieties accompany the eclogites? According to Smulikowski (1964) and Bakun-Czubarow (1968) the eclogites are enveloped by secondary amphibolites. According to the existing geological maps of the area (Frąckiewicz, Teisseyre 1967; Cymerman, Cwojdziński 1986; Cwojdziński 1983) similar amphibolites occur within the Gierałtów gneisses and the Stronie series. In the Gierałtów unit the eclogites form interlayers in granulites.

Let us start the discussion on the history of the eclogites in the structural plan of the Śnieżnik massif with answering the question of the significance and origin in this structural plan. The plan reflects, first of all, the position of the S_3 planar structures which are widespread and best visible throughout the area, and whose trend is followed, due to tectonic transposition, by majority of older structural elements together with boundaries of lithofacial units. These boundaries define cartographically discernible fold units, produced during the D_4 deformation event as antiforms and synforms. In the younger deformational events these units were only slightly modified.

It turns out that the position of eclogites within these units is variable. The eclogites from Międzygórze and Nowa Wieś, as well as those from Wojtówka, occur within core zones of unquestionable antiforms or domes. The structural position of other occurrences of eclogites is, however, different or more difficult to be unequivocally explained. Namely, in the Gierałtów unit the eclogites are known from its both limbs, i.e. from the north-western limb (the occurrence in Strachocin) and from its south-eastern limb (the occurrence in Czernica), as well as from the core of this unit as intercalations alternating with granulites. Don (1964) described this structure as an anticlinorial one but Oberc (1972) terms it Stary Gierałtów - Nowe Wilamowice syncline. In the area of the Rychlebskie Mts. in the Czech Republic, where this unit continues towards the northeast, it is also described as a syncline (among others by Pouba *et al.*, 1985). Cymerman (1988), to reconcile a synclinal pattern of foliation with the generally held opinion about the anticlinal structure of the Gierałtów unit, considers it a balloon-like form. According to his views, in the present intersection level a basal part of that peculiar structure crops out. The present author's investigations support the view of the synformal character of this unit resulting from the arrangement of the S_3 foliation within the Gierałtów gneisses which compose its limbs. The next eclogite occurrence, in Nowa Morawa, is, according to Kasza (1964), located in the Śnieżnik synclinorium and constitutes a part of the eastern limb of the syncline termed the Pustosza - Siekierzyn syncline.

We can thus see that eclogite bodies occur within various rock varieties at completely random positions in the fold or dome-like structural plan produced during the fourth deformational event D_4. The above observations undermine the opinion relating the eclogites, in both – their temporal and spatial aspects, to the formation of antiforms or granite gneiss domes. These rocks must have been emplaced into the Snieżnik complex before the D_4 event.

STUDY OF MINOR STRUCTURES IN GRANULITES AND ECLOGITES ON THE BACKGROUND OF MESOSTRUCTURAL ANALYSIS OF THE GNEISSIC SERIES

After having recognized mesoscopically the sequence and nature of minor tectonic phenomena in the gneissic series, the author undertook a similar study within the granulites and eclogite bodies.

In the granulitic series, which contains numerous eclogite intercalations, only one outcrop exists, located in Stary Gierałtów, in an escarpment on the right bank of the Biała Lądecka river. In the west part of this outcrop a distinct lamination, probably S_1, can be observed, intensely folded into F_2 folds with weakly developed axial plane crystallization schistosity S_2 or S_{2+3} (Pl. VI). The whole outcrop is strongly weathered. Dark S_1 laminae are partially boudinaged, and in the eastern part of the outcrop (not visible on the photos in Pl. VI) refolded by F_4 folds. The spatial orientation of these mesostructures is shown on diagram 31 (Fig. 2).

The above presented observations, collected, by necessity, from only one outcrop, are insufficient to explain, even in a general way, the structural development of the Stary Gierałtów granulitic series, which occupies on the Polish territory an area of about 5 km^2. Due to such situation it was necessary to collect a considerable number of hand specimens from loose blocks of the weathering cover of the granulites and to carry mesostructural examinations on polished slabs. These examples revealed a wide variety of minor structures, mostly of tectonic origin. The representative examples of these forms are shown in plates VII to XII. Some of them point out to a highly complex development of the mesostructures in the granulites (Pl. VII, *1*). It can not be excluded that we have to do here with S_0 lamination deformed into an intrafolial fold F_1 adjacent to the S_1 lamination (upper part of the photo), which is parallel to its axial plane. In some specimens, particularly valuable cases of primary contacts of granulites and eclogites were found. In more complex situations, as e.g. in photo *2*, Pl. VII, it was not clear whether we have to do with primary interfingering of both rock varieties or with their tectonic contact due to refolding.

Most of the mesostructural data concerning the granulitic series come from granulites and eclogites characterized by alternation of light and dark laminae and streaks, presumably S_1 or S_{0+1}. They are often deformed into F_2 folds, mostly tight and similar (Pl. VIII, Pl. IX, *1*) or disharmonious (Pl. IX, *2*; Pl. X, *1*).

A relatively widespread phenomenon in the granulites, or rather garnet-bearing gneisses from Stary Gierałtów, is local S_3 gneissosity. It is defined by closely spaced surfaces within which garnets are replaced by biotite flakes (Pl. X, *2*, Pl. XI), often linearly dispersed in the form of strongly elongated lenses or distinctly flattened spindles. It has also been noted that these phenomena occur almost parallel to axial planes of relic folds (Pl. XII, *1*). Presumably we have to do here with the development of younger structures S_3 and L_3 concordant with the axial planes of older F_2 folds.

Among other observations, enriching our general knowledge on the granulitic series, a spherical form, 6 cm in diameter, composed entirely of coarse-crystalline garnets and zoisite (Pl. XII, *2*), found in a loose block, attracted the author's attention. The sphere is embedded in finely laminated dark granulite. It shows "tails" with characteristic inflexions formed due to rotation. It is probably an equivalent to what is called in the English literature a "snowball structure". Such structures might have much larger size, as evidenced by large fragments found in blocks (Pl. XII, *3*). Mineral composition and microstructures of the rocks were studied in cooperation with Dr. C. Juroszek from the Department of Mineralogy and Petrography of Wrocław University. The discussed series was earlier extensively described by petrologists.

Investigations of Kozłowski (1965) revealed that the Stary Gierałtów granulitic series is a product of a complex metamorphic evolution, which took place in three successive stages: 1 – the early stage, in which the mineral assemblage crystallized, preceding formation of garnets; 2 – the main stage, during which the garnets grew at the cost of other minerals; 3 – the late stage, in which mineral transformation, younger than the formation of garnets, took place (among others the biotitization of garnets).

Microscopic observations of C. Juroszek, concentrated mostly on studying the relation biotite/garnet, are in perfect agreement with the three-stage evolution of the granulitic series as outlined by Kozłowski (1965). Moreover C. Juroszek found two generations of biotite: the older biotite, preceding the blastesis of garnets and the younger biotite, formed mostly due to garnet decomposition. In the discussion on that problem the present author's attention was drawn to the question of the time relation between the mineral and tectonic transformations of this series. As yet we did not manage to analyse this problem in greater detail. Nevertheless, we perceive certain possibilities of correlation in time of the effects of mineral transformations with the development of minor tectonic forms. Here are two examples:

– The first example enlightens the relation between the crystallization of older biotite generation and the development of the F_2 fold, on the basis of microscopic picture of a thin section made in the core region of a F_2 mesofold in granulites, cut parallel to the AC structural coordinates. At the background of relatively uniformly dispersed and rather chaotically orientated biotite flakes a streak is visible, within which many of the flakes are orientated symmetrically to the axial plane of the mesofold, thus defining a divergent fan (divergent towards the hinge of the fold). This symmetry may point to a simultaneous development of biotite blastesis and the F_2 folds formation;

– The second example concerns the relation between the blastesis of the younger biotite generation and the formation of the S_3 gneissosity in the garnet-bearing gneisses of the granulitic series. The mesoscopic description of the spatial relations of these phenomena was discussed above, with reference to photographs of polished slabs (Pl. X, *2*, Pl. XI, Pl. XII, *1*). The microscopic observations of C. Juroszek suggest that the discontinuities associated with the development of the S_3 gneissosity and the S_3 lineation created favorable conditions for fluid penetration, leading e.g. to the biotitization of garnets.

The above examples allowed the time correlation of the blastesis of garnets and omphacite with respect to the development of F_2 folds and S_3 gneissosity. From the papers of Smulikowski (1963) and Kozłowski (1965) it appears that the blasts of these minerals contain intergrowths of older biotite generation. If this biotite were actually coeval with the F_2 folds, as suggested by the first example, then the garnetization and omphacite blastesis in the Stary Gierałtów granulitic series must have taken place after the formation of F_2 folds but before the development of the S_3 gneissosity and L_3 lineation. Scarce analytic material that forms the basis of the above interpretation, enables the author to consider it only a working hypothesis.

The eclogites located outside the granulitic series are known in the area under study from numerous crags within the relatively well exposed Gierałtów gneisses and, in one case, within the Stronie series paragneisses. The present author began studying these rocks mesostructurally in 1988 in the northern part of the Międzygórze unit. Investigated were eclogite bodies in numerous exposures, as well as the crags of the Gierałtów gneisses within which the eclogites occur (Fig. 1, observation points "a" to "l"). The results of structural analysis of these rocks were presented in the Międzygórze field conference volume (Dumicz 1989a). In 1989 and 1990 the investigations were extended onto remaining occurrences of eclogites and adjacent rocks of the Śnieżnik massif (Fig. 1, observation points 1 to 30, and 32 to 46). The spatial orientation of the studied mesostructures is shown on stereograms 1 to 30 and 32 to 46 in Fig. 2. The stereograms are annotated with the same symbols as the corresponding observation points on the map (Fig. 1).

On the basis of field observations and the analysis of distribution of mesostructures on the stereograms, the latter carried out separately for the gneisses and the eclogites, an attempt was made to relate tectonic structures found in these rocks to four deformational events D_1 to D_4 probably common to all the rock series. The results (in part already published – Dumicz 1989a) revealed that these rocks reacted differently to tectonometamorphic processes. It was best manifested in the effects of the D_3 deformation event. The gneissic series, represented here mostly by the Gierałtów gneisses, was more ductile than the eclogites and responded to deformation in various ways: (1) by crenulation of the S_1 lamination producing the L_3 crenulation lineation and the local S_3 crenulation cleavage, (2) by zonal transformation of the latter cleavage into the S_3 gneissosity and of the L_3 crenulation lineation into rodding. This process eventually resulted in the formation of lenticular to banded variety of the Śnieżnik type gneisses, the destruction of lamination S_1 in zones of intense tectonometamorphic changes, and the development of a new S_3 lamination. In eclogites, on the other hand, at the same time there developed the S_3 cleavage, relatively well visible in the varieties affected by amphibolitization processes (Pl. XIII, Pl. XIV, *1*). It is defined by tabular arrangement of thin lenses and laminae composed of plagioclases and by parallel orientation of fine crystals of hornblende.

As yet not enough information exists for a detailed comparison of the results of D_1 and D_2 deformation events in the gneissic series and the eclogites in the Śnieżnik massif. It may be assumed, however, with a significant degree of probability, that the protolith of the eclogites and the amphibolites formed by alterations of eclogites, was emplaced into the gneissic series prior to the D_2 deformation. However, no proof was found yet, that the S_1 lamination in the Gierałtów gneisses and the planar structures in the eclogites, termed the S_1 lamination, are of the same age and origin. The S_1 lamination, widespread and distinctly marked in the Gierałtów gneisses displays features of metamorphic lamination, while the lamination termed S_1 in the eclogites is rare and inhomogeneous (Pl. XIV, *2*, Pl. XV, *1*), hard to identify and, in some cases, it reveals features typical of fluidal structures (Pl. XV, *2*). It was not possible so far to prove whether the latter are preserved relics of fluidal structures of igneous rocks that might have been a part of the Stronie supracrustal series that survived the D_1 deformation. Such fluidal structures could have also been present in the younger rocks which may have appeared in this series, or possibly, in the Gierałtów gneisses as well, during the D_1 deformation, or subsequently to the D_1 but prior to the D_2 event. Namely, the boundary between the eclogites and the Gierałtów gneisses is concordantly deformed into F_2 folds (Pl. XVI, *1*), which was noticed in Międzygórze, where the contact is exposed. Moreover, a tight, isoclinal fold was found in the eclogites close to Strachocin near Stronie Śląskie (Pl. XVI, *2*), with a shape typical of the F_2 folds in the Gierałtów gneisses near Międzygórze (Pl. I, *1*).

It should be stressed, however, that except for the granulitic area, the vast majority of the mesostructures discussed here come from amphibolites which form envelopes separating the eclogites from the gneissic series. The eclogites composing the inner part of the amphibolite lenses are massive rocks that lack mesostructures. Only sporadically one can perceive weak lamination or banding. In the case of these eclogites no equivocal answer was obtained from the mesostructural analysis to the question whether they were genetically related to the Stronie series. It is, however, plausible to assume that the common history of development of both eclogites and the Stronie series began prior to the formation of the F_2 folds. It can not be excluded, however, that these eclogites constitute an integral part of the Stronie series, as suggested by Smulikowski (1964). In the case of eclogites occurring as intercalations within the granulites of the Stary Gierałtów series, mesostructural analysis proves fully concordant structural development of both rock varieties, and the D_1 to D_4 deformation effects in them (mostly found in loose blocks) can be easily compared with the corresponding structures within the Gierałtów gneisses, which are also known as intercalations in the granulitic series.

RADIOMETRIC AGES OF THE ROCKS OF THE ŚNIEŻNIK COMPLEX AND OF MINERAL TRANSFORMATIONS WITHIN THE ROCKS IN RELATION TO THE MAIN DEFORMATIONAL EVENTS

Important for establishing the chronology of geological phenomena in the Śnieżnik massif proved to be the results of radiometric investigations made for the rocks of this region by two research teams, namely, by the Polish-French team (Borkowska, Choukroune, Hameurt and Martineau) and the Polish-American team (Brueckner, Medaris and Bakun-Czubarow). The data were published in papers of field conference held in Międzygórze on 11 - 12 September, 1989, and presented in lectures given by Borkowska and Bakun-Czubarow at the conference devoted to the memory of Kazimierz Smulikowski on 11 - 12 October, 1990 in Warsaw.

High concentration of research work carried out in various domains of geology in the Śnieżnik massif recently resulted in a great number of interesting data. They concern quite various phenomena and make geological evolution of that region more understandable, pointing, at the same time, to its complex character. Extremely interesting in this respect is the comparison of radiometric ages of rocks and mineral transformations with the stages of tectonic deformations, made within the frame of the geodynamical model of the Śnieżnik massif introduced by Borkowska *et al.* (1990).

The new age determinations by Sm-Nd (Brueckner *et al.* 1991) and by U-Pb methods (J. J. Peucat, personal communication of M. Borkowska) indicate that the age of the emplacement of an eclogite protolith in the Śnieżnik massif corresponded to the Cadomian orogeny. Therefore this process must have taken place during the time of formation of the Stronie series for which the Late Proterozoic - Early Palaeozoic age is suggested (Fischer 1935; Gunia 1984). According to the model proposed by Borkowska *et al.* (1990), the emplacement of the protolith took place in the oceanic crust (?). Its folding together with the Stronie series (Dumicz 1989a) occurred in a collision zone. This interpretation seems plausible, in particular with respect to the eclogite bodies in the gneissic series.

The radiometric dating obtained by Borkowska *et al.* (1989, 1990) by the Rb-Sr method concerned, among others, the Gierałtów gneisses and established their age as 464 ± 18 Ma. It is surprising that these gneisses, being, according to the views of the cited authors, of igneous origin, show identical sequence and very similar morphology of mesostructures to those in the paragneisses of the Stronie series, into which they gradually pass. As suggested by Borkowska *et al.* the protolith of the dated Gierałtów gneisses was a granitic, originally practically isotropic rock which intruded into the Stronie series. According to the observations of the present author, the Stronie series, on the contrary, possessed originally a sedimentary anisotropy. In such a case different reactions to the tectonometamorphic processes should be expected. However, this was not the case. If the igneous origin was ascribed to those rocks only because of their chemistry, one should remember here the view of Ansilewski (1966), who derived the Gierałtów gneisses from, among others, an arcosic sedimentary formation. Also Borkowska *et al.* (1990) noticed the presence of other gneisses included into the Gierałtów member, but of probably different age and origin from those which these authors considered as orthoderived gneisses and which they dated radiometrically. They did not exclude that some of these other gneisses could be considered as retrograded granulites.

The successive data acquired by Borkowska *et al.* (1990) by the Rb-Sr method point to 395 ± 35 Ma as the age of the protolith of the Śnieżnik gneisses. The radiometrically obtained sequence of events, pointing to the formation of the Gierałtów gneisses before the Śnieżnik gneisses, finds again its justification in the mesostructural analysis (the effects of the D_1 and D_2 deformations are present in the Gierałtów gneisses and absent in the Śnieżnik gneisses). The D_3 deformation affected already both the Gierałtów gneisses and the granitic protolith of the Śnieżnik gneisses.

In the papers of Dumicz (1976, 1979, 1988, 1989b) these phases, termed also events, were characterized in the following way:

The first event, D_1, occurred in the tectogenic period of the Early Variscan subcycle and presumably took place in a tangential compression field (formation of metamorphic lamination and S_1 crystallization foliation, in general concordantly superposed on S_0 sedimentary lamination development, of F_1 folds, which are very rarely found as relics).

The second event, D_2, occurred in the orogenic stage of the Early Variscan subcycle and presumably took place in a vertical compression regime, associated with the load of an overburden (microcline blastesis leading to the formation of the Śnieżnik gneisses, formation of the F_2 folds, mostly similar, and S_2 crenulation cleavage, mostly concordant with the axial surfaces of the F_2 folds, which were subhorizontal at that time).

The third, D_3, event commenced the younger subcycle of the Variscan transformations. It affected the fully consolidated and rigid Early Variscan tectogene and took place, as it seems, in a field affected by two forces operating in a vertical plane, with vectors orientated approximately parallel to the surfaces of the S_2 cleavage, which were subhorizontal at that time. This pattern had a decisive influence on the further course of tectonic and metamorphic events. It led to mechanical reactivation of physical discontinuities dating from the previous deformational event, i.e. mostly the S_2 cleavage. At the first stage there prevailed dynamic processes, and at the final stage, the phenomena of recrystallization and blastesis occurring zonally with high intensity and leading to metamorphic rejuvenation of the Gierałtów gneisses and gneissification of the granitic material of the Śnieżnik gneisses (widespread S_3 gneissification of gneissic series, zonal development of S_3, S_{2+3}, S_{1+3} metamorphic lamination and production of the L_3 lineation mostly of intersection character: S_1/S_3 in the Gierałtów gneisses.

In his previous works the present author ascribed the D_1 and D_2 events to folding of the Orkney phase at the turn of the Early and

Middle Devonian (385 - 370 Ma) and the D_3 event to the Sudetic phase at the turn of the Early and Late Carboniferous (325 - 320 Ma). In the presented sequence of the D_1-D_3 tectonometamorphic events a very interesting place is occupied by the episode of HP metamorphism, dated by Brueckner *et al.* (1989, 1991) as well as Bakun-Czubarow and Brueckner (1991) at 352-329 Ma. Borkowska *et al.* (1990) explain the eclogitic metamorphism by a collision related to large crustal overthrusting. In the chronology of the D_1-D_3 events this process occurred after the tectogenic phases (D_1 and D_2) and before the phase of transformation (D_3) of the Early Variscan tectogene.

If the above presented sequence is confirmed in the future research work it will mean that the HP metamorphic episode took place in a peculiar moment in the development of the Early Variscan tectogene, i.e. after the F_2 folding of the Stronie series, the Gierałtów series and the granulitic series together with thin intercalations of the eclogite protolith, and after emplacement of the granite body being the protolith of the Śnieżnik gneiss.

In the hitherto published papers of Dumicz (1976, 1979, 1989b) the maximum piling of rock masses in the Śnieżnik massif was referred to the D_1 tectogenic folding event preceding the emplacement of the Śnieżnik gneiss protolith. This interpretation is justified now in the geodynamical model of Borkowska *et al.* (1990), in which, the high pressure metamorphism with the theoretically assumed, but not dated isotopically, age of 420 Ma occurs just in the period preceding the formation of the protolith (395 Ma) of the Śnieżnik gneisses and is the result of intense folding of the oceanic crust (?) together with the Stronie series in a zone of collision of crustal domains.

The radiometric data (352 - 329 Ma) relating the eclogitic metamorphism to the period after the emplacement of the Śnieżnik gneiss protolith and after the D_2 orogenic event are, for a geologist, very surprising and leave open many questions. At the present state of knowledge it is difficult to explain the observed phenomena in a convincing way with the principles of the plate tectonics. Perhaps this situation is due to an error made somewhere when assessing the age of main geological events in the Śnieżnik massif.

Acknowledgements

The research was done as a part of CPBP project coordinated by the Institute of Geological Sciences of the Polish Academy of Sciences. The last phase of investigations was financed from KBN grant no. 604409101. The principal points of the article were already presented on 11 - 12 October 1990, on the conference in Warsaw dedicated to the memory of Kazimierz Smulikowski, and on the lecture given on 26 November 1990, on the meeting of the Wrocław branch of the Polish Geological Society.

The material presented in the article refers to the problems discussed by the author earlier in the paper "The sequence of gneissic members of the Śnieżnik massif in the light of mesostructural analysis" published in *Geologia Sudetica*, vol. 24, 1-2, 1989.

My participation in the research work devoted to the geological evolution of the Śnieżnik massif was possible thanks to financial support from the Institute of Geological Sciences of the Polish Academy of Sciences and to the kindness I experienced from a part of the Scientific Council and from the board of directors of that institution. I would like to express my sincere gratitude to its director, Professor Maria Borkowska, for creating atmosphere favourable to scientific creativity during my long-lasting cooperation with the Institute and for valuable discussions on the geological problems of the Sudetes.

I would like to thank very warmly Professor Irena Wojciechowska for many years of cooperation in solving complex geological problems of the Kłodzko district.

I am particularly grateful to Professor Jerzy Don for the comprehensive discussions on the sequence and age of metamorphic complexes of the Sudetes. Our positions in this respect are different! And this is why his works devoted to this problem were so much inspiring in my own research.

Translated by Paweł Aleksandrowski

REFERENCES

ANSILEWSKI J., 1966. Petrografia metamorfiku Gór Bialskich. Petrography of the gneiss area of the Bialskie Mts. *Geol. Sudetica*, 2, 121 – 260.

BAKUN-CZUBAROW N., 1968. Geochemical characteristics of eclogites from the environs of Nowa Wieś in the region of Śnieżnik Kłodzki. Geochemiczna charakterystyka eklogitów okolic Nowej Wsi w regionie Śnieżnika Kłodzkiego. *Arch. Miner.*, 28, 1, 243 – 382.

BAKUN-CZUBAROW N., 1990: Eklogity Gór Śnieżnickich – 20 lat później. Konferencja pt. "W kręgu zainteresowań Kazimierza Smulikowskiego". 11-12.10.1990. Streszczenie referatów.

BAKUN-CZUBAROW N., BRUECKNER H. K., 1991. Eklogity właściwe i granulity omfacytowe jako wskaźniki waryscyjskiego epizodu wysokociśnieniowego w metamorfiku Śnieżnika. *In:* Następstwo serii skalnych masywu Śnieżnika w świetle kartografii geologicznej, analizy strukturalnej i badań radiometrycznych. Mater. konfer. teren., Lądek Zdrój, 18-19.10.1991r., 98 – 121.

BALL T. H., FLEMING P. D., RUBENACH M. J., 1986. Porphiroblast nucleation, growth and dissolution in regional metamorphic rocks as a function of deformation partitioning during foliation development. *Journal of Metamorphic Geol.*, 4, 37 – 67.

BORKOWSKA M., CHOUKROUNE P., HAMEURT J., MARTINEAU F., 1989. Origin and age of the Caledonian-Variscan granite-gneisses of the Śnieżnik metamorphic area (Central Sudetes). Indicators of structural evolution in polyphase deformed metamorphic complexes: criteria for the distinction of para and orthogneisses, the Orlica-Śnieżnik dome, West Sudetes. Field workshop in Poland, 59 – 71.

BORKOWSKA M., CHOUKROUNE P., HAMEURT J., MARTINEAU F., 1990. A geochemical investigation of the age, significance and structural evolution of the Caledonian-Variscan granite-gneisses of the Śnieżnik metamorphic area (Central Sudetes, Poland). Wiek, znaczenie i ewolucja strukturalna kaledońsko-waryscyjskich granitognejsów metamorfiku Śnieżnika w Sudetach Środkowych – studium geochemiczne. *Geol. Sudetica*, 24, 1 – 27.

BRUECKNER H. K., MEDARIS L. G., BAKUN-CZUBAROW N., 1989. First data on the Nd and Sr age and isotope patterns from Hercynian eclogites and garnet pyroxenite of the Śnieżnik metamorphic massif in the Sudetes and of the other occurrences within Moldanubian zone of the Bohemian Massif. Indicators of structure evolution in polyphase deformed metamorphic complexes; criteria for the distinction of para and orthogneisses, the Orlica-Śnieżnik dome, West Sudetes. Field workshop in Poland, 72 – 74.

BRUECKNER H. K., MEDARIS L. G. JR., BAKUN-CZUBAROW N., 1991. Nd and Sr age and isotope patterns from Variscan eclogites of the eastern Bohemian Massif. *N. Jb. Miner. Abh.*, 163, 2, 3, 169 – 196.

BURCHART J., 1960. O granitoidach jawornickich Sudetów Wschodnich. On the Jawornik Granitoids (Eastern Sudetes). *Arch. Miner.*, 22, 2, 237 – 348.

CWOJDZIŃSKI S., 1983. Mapa geologiczna Sudetów 1:25 000, arkusz Stronie Śląskie. Wydawnictwa Geologiczne. Warszawa.

CYMERMAN Z., 1988. Objaśnienia do szczegółowej mapy geologicznej Sudetów 1:25000 ark. Strachocin i Bielice, Wydawnictwa Geologiczne. Warszawa.

CYMERMAN Z., CWOJDZIŃSKI S., 1986. Szczegółowa mapa geologiczna Sudetów 1:25 000 arkusz Strachocin-Bielice. Wydawnictwa Geologiczne. Warszawa.

DON J., 1964. Góry Złote i Krowiarki jako elementy składowe metamorfiku Śnieżnika. The Złote and Krowiarki Mts. as structural elements of the Śnieżnik metamorphic massif. *Geol. Sudetica*, 1, 79 – 117.

DON J., 1989. On the position of the eclogites within the gneisses of Międzygórze (Śnieżnik metamorphic massif - Sudetes). *In:* Indicators of structural evolution in polyphase deformed metamorphic complexes: criteria for the distinction of para and orthogneisses, the Orlica-Śnieżnik dome, West Sudetes. Field workshop in Poland, 44 – 58.

DON J., DUMICZ M., WOJCIECHOWSKA I., ŻELAŹNIEWICZ A., 1990. Lithology and tectonics of the Orlica-Śnieżnik dome, Sudetes – Recent state of knowledge. *N. Jb. Geol. Paläent. Abh.*, 179, 159 – 188.

DUMICZ M., 1976. Próba wyjaśnienia tektogenezy serii zmetamorfizowanych Ziemi Kłodzkiej. *In:* Problem wieku deformacji serii zmetamorfizowanych Ziemi Kłodzkiej. Materiały Konferencji Terenowej 11-12.09.1976. Uniwersytet Wrocławski, Wrocław, 9 – 37.

DUMICZ M., 1979. Tectogenesis of the metamorphosed series of the Kłodzko District: a tentative explanation. Próba wyjaśnienia tektogenezy serii zmetamorfizowanych Ziemi Kłodzkiej. *Geol. Sudetica*, 14, 2, 29 – 46.

DUMICZ M., 1988. Strefa tektoniczna Złoty Stok-Skrzynka w świetle analizy mezostrukturalnej metamorfiku Lądka-Śnieżnika. Złoty Stok-Skrzynka structural element in the light of mesostructural analysis of Lądek-Śnieżnik. *Geol. Sudetica*, 23, 2, 83 – 106.

DUMICZ M., 1989a. The interrelationship of eclogites and gneiss series within the Międzygórze unit in the light of mesostructural study. *In:* Indicator of structural evolution in polyphase deformed metamorphic complexes: criteria for the distinction of para and orthogneisses, Orlica-Śnieżnik dome, West Sudetes. Field workshop in Poland, 31 – 43.

DUMICZ M., 1989b. Następstwo serii gnejsowych masywu Śnieżnika w świetle analizy mezostrukturalnej wybranych obszarów w jednostkach geologicznych Międzygórza i Gierałtowa. The Śnieżnik Mts. gneisses sequence in the light of mesostructural analysis of some areas of the Międzygórze and Gierałtów units. *Geol. Sudetica*, 24, 139 – 189.

DUMICZ M., 1991. Stosunek eklogitów do serii gnejsowej jednostki Międzygórza w świetle analizy mezostrukturalnej. The interrelationship of eclogites and gneisses series within the Międzygórze unit in the light of mesostructural study. *Acta Universitatis Wratislaviensis. Pr. Geol.-Mineral.*, 19, 31 – 46.

FISHER G., 1935: Der Bau des Glatzer Schneegebirges. *Jb. Pr. Geol. L. A.*, 56. 712 – 732.

FRĄCKIEWICZ W., TEISSEYRE H., 1976. Szczegółowa mapa geologiczna Sudetów 1:25 000 ark. Międzygórze. Wydawnictwa Geologiczne. Warszawa.

GUNIA T., 1984. Mikroskamieniałości z łupków kwarcytowych okolicy Goszowa w masywie Śnieżnika Kłodzkiego (Sudety Środkowe). Microfossils from the quartzite schists in vicinity of Goszów, Śnieżnik Kłodzki massif, Central Sudetes. *Geol. Sudetica*, 8, 2, 47 – 62.

KASZA L., 1964. Budowa geologiczna górnego dorzecza Białej Lądeckiej. Geology of the upper basin of Biała Lądecka stream. *Geol. Sudetica*, 1, 119 – 167.

KASZA L., 1967. Szczegółowa mapa geologiczna Sudetów 1: 25 000 ark. Nowa Morawa. Wydawnictwa Geologiczne. Warszawa.

KOZŁOWSKA-KOCH M., 1973. Polimetamorfity strefy tektonicznej Złoty Stok-Skrzynka w Sudetach. Polymetamorphites of the Złoty Stok-Skrzynka dislocation zone. *Geol. Sudetica*, 8, 121 – 160.

KOZŁOWSKI K., 1965. Kompleks granulitowy Starego Gierałtowa w Górach Złotych. The granulitic complex of Stary Gierałtów - East Sudetes. *Arch. Miner.*, 25, 5 – 122.

OBERC J., 1957. Zagadnienie geologii metamorfiku zachodniej części Gór Bialskich i obniżenia Stronia Śląskiego. Przewodnik 30 Zjazdu Pol. Tow. Geol. w Ziemi Kłodzkiej. Wrocław, 72 – 89.

OBERC J., 1972. Budowa geologiczna Polski, t. 4, Tektonika, cz. 2: Sudety i obszary przyległe. Inst. Geol., Wydawnictwa Geologiczne. Warszawa.

POUBA Z., PADERA K., FIALA J., 1985. Omphacite granulite from the NE marginal area of the Bohemian Massif (Rychleby Mts.). *N. Jb. Miner. Abh.*, 151, 1, 29 – 52.

SMULIKOWSKI K., 1957. Formacje krystaliczne grupy górskiej Śnieżnika Kłodzkiego. Przew. 30 Zjazdu Pol. Tow. Geol. w Ziemi Kłodzkiej. Wrocław, 37 – 54.

SMULIKOWSKI K.. 1963. Les eclogites et leurs transformations an milieu des gneiss du massif de Śnieżnik dans les Sudetes. *Bull. Soc. Géol. France*, 7-e serie. 5, 5, 852 – 862.

SMULIKOWSKI K., 1964. Le problème des éclogites. Zagadnienie eklogitów. *Geol. Sudetica*, 1, 13 – 77.

SMULIKOWSKI K., 1967. Eklogity Gór Śnieżnickich w Sudetach. Eclogites of the Śnieżnik Mts. *Geol. Sudetica*, 3, 107 – 130.

SMULIKOWSKI K., 1973. Le roches metamorphiques du Mont Śnieżnik et la région de Lądek. Revue des problemes geologiques des zones profondes de l'ecorce terrestre en Basse Silesie. Wydawnictwa Geologiczne. Warszawa. 77 – 102.

SMULIKOWSKI K., 1976. Ultramafic rocks from the vicinity of Złoty Stok (Lower Silesia). *Bull. Acad. Sci., Sér. Sc. de la Terre*, 24, 3-4, 244 – 251.

SMULIKOWSKI K., 1979. Ewolucja polimetamorficzna Krystaliniku Śnieżnika Kłodzkiego i Gór Złotych w Sudetach. Polymetamorphic Evolution of the Crystalline Complex of Śnieżnik and Góry Złote Mts. *Geol. Sudetica*, 14, 7 – 76.

TEISSEYRE H., 1957. Budowa geologiczna okolic Międzygórza. Przewodnik 30 Zjazdu Pol. Tow. Geol. w Ziemi Kłodzkiej. Wrocław, 54 – 72.

EXPLANATIONS OF PLATES

Plate I

1 — Tight, isoclinal F_2 fold. Gierałtów gneisses near Międzygórze

2 — Tight F_2 folds in the Gierałtów gneisses near Międzygórze

Plate II

Stages of transformation of S_1 lamination into S_3 lamination (1 to 3). Description in the text. Environs of Gierałtów

Plate III

1 — S_1 and S_3 laminations in the Gierałtów gneiss. Description in the text. Environs of Międzygórze

2 — S_3 gneissosity in banded-lenticular gneisses near Nowa Wieś

Plate IV

1 — Asymmetric F_4 fold in the Śnieżnik gneiss. Environs of Karpno

2 — Same fold as in Photo 1, in specimen. Description in the text

3 — L_3 lineation (visible at the bottom) due to S_1/S_3 intersection. Environs of Lądek Zdrój

Plate V

1 — Variable orientation of L_3 lineation due to discordant superposition of S_3 gneissosity onto S_1 lamination folded by F_2 folds. Environs of Karpno

2 — Same as in Photo 1, from a loose block of the same area

Plate VI

1 — Exposure of granulitic series, Stary Gierałtów. Description in the text

2 — Lower right corner of Photo 1 enlarged

Plate VII

1 — S_0 (?) lamination deformed by F_2 folds (bottom) and lamination S_1 (top) in granulites

2 — Contact zone between eclogites and granulites

Plate VIII

Similar folds in granulitic series enriched in biotite (Photo 1) and poor in biotite (Photo 2)

Plate IX

1 — Intrafolial folds in granulites (bottom); possibly due to deformation of S_0 lamination

2 — Disharmonic F_2 folds in granulites

Plate X

1 — Disharmonic folds in amphibolites of the granulitic series

2 — Coarse-grained S_3 gneissosity in granulitic series

Plate XI

1 — Medium-grained S_3 gneissosity in granulitic series

2 — Fine-grained S_3 gneissosity in granulitic series

Plate XII

1 — F_2 fold in granulitic series, with visible gneissosity (presumably S_3), concordant with its axial plane

2 — Spherical form composed of garnet and zoisite, enveloped by dark, fine-laminated granulite. Possibly it represents primary concretion transformed into a snowball structure

3 — Structure of the same type as that from in Photo 2, but of larger size

Plate XIII

S_3 cleavage in eclogites in Nowa Morawa (1) and in Międzygórze (2)

Plate XIV

1 — S_3 gneissosity in eclogites near Międzygórze

2 — Contact zone of paragneisses and eclogites near Nowa Morawa

Plate XV

1 — S_1 lamination in eclogite from Międzygórze

2 — Fluidal structures (textures) in eclogite near Międzygórze

Plate XVI

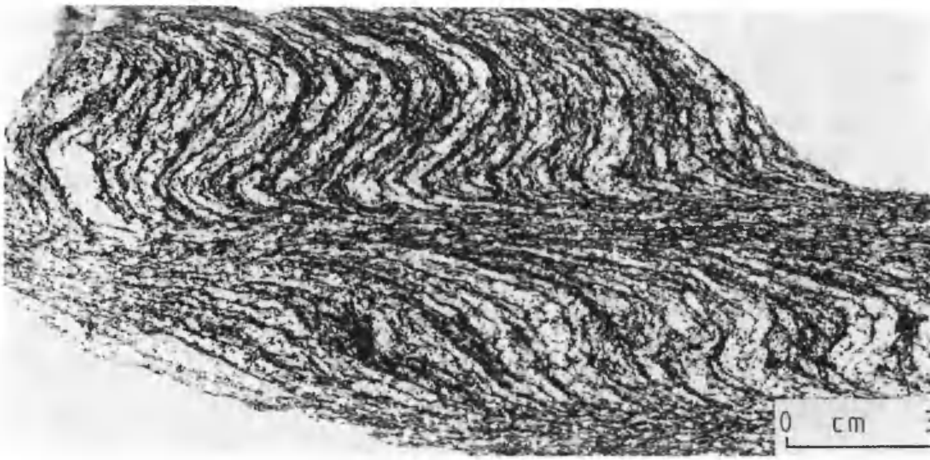
1 — Contact zone of Gierałtów gneisses and eclogites, deformed by F_2 fold. Międzygórze

2 — Tight, isoclinal F_2 fold in eclogite rock. Strachocin near Stronie Śląskie

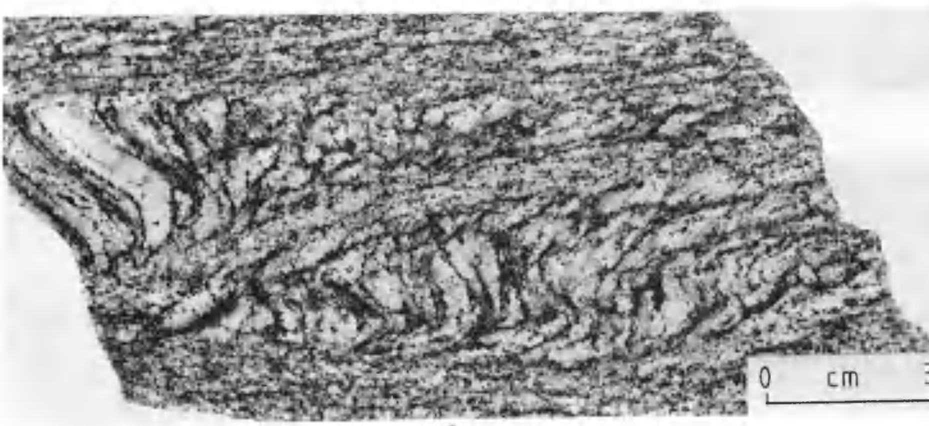
1

2

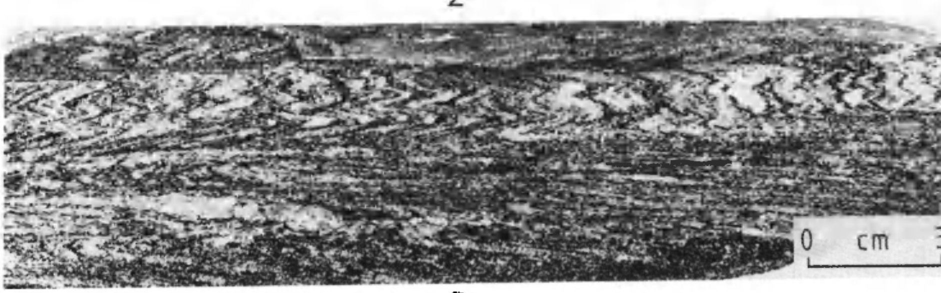
Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis



1

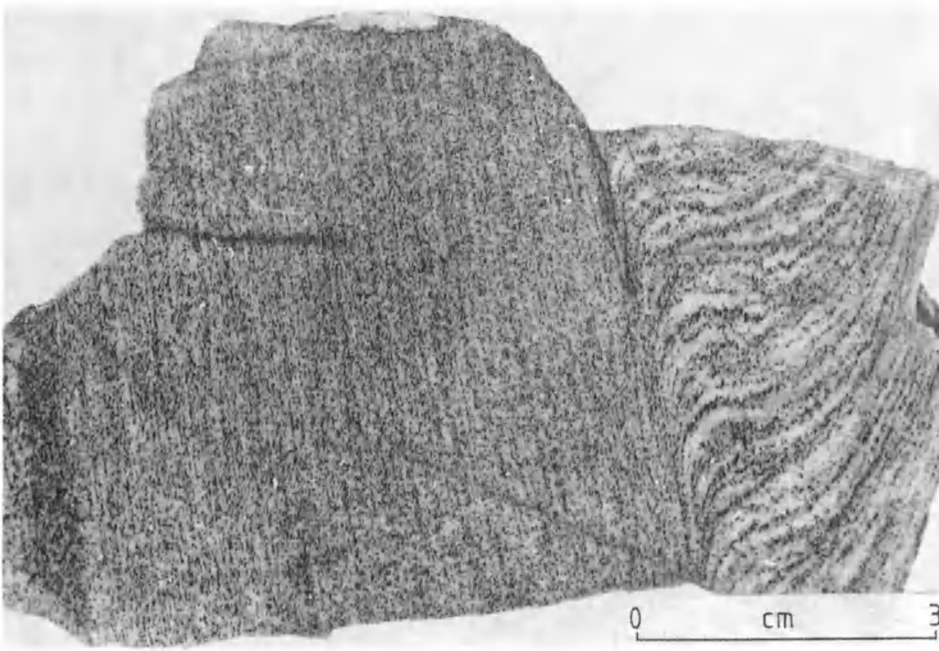


2

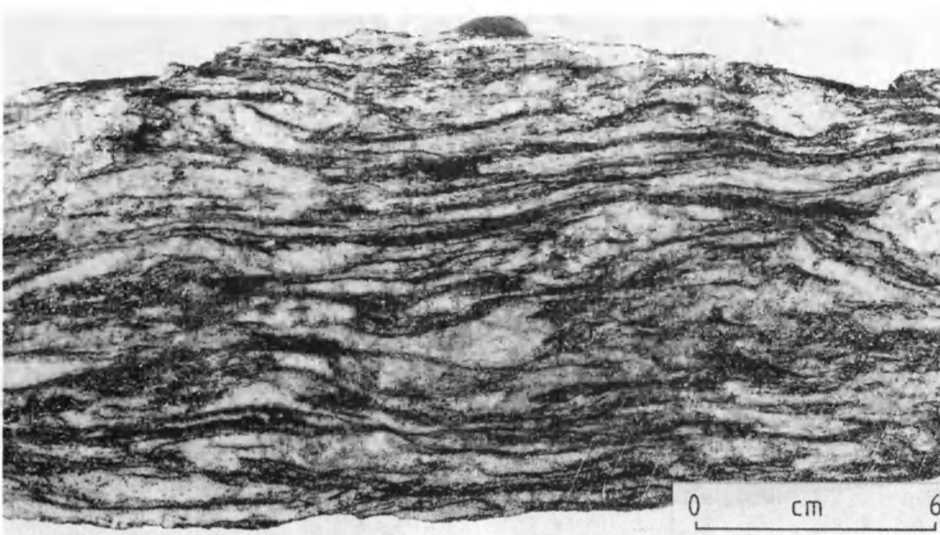


3

Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis

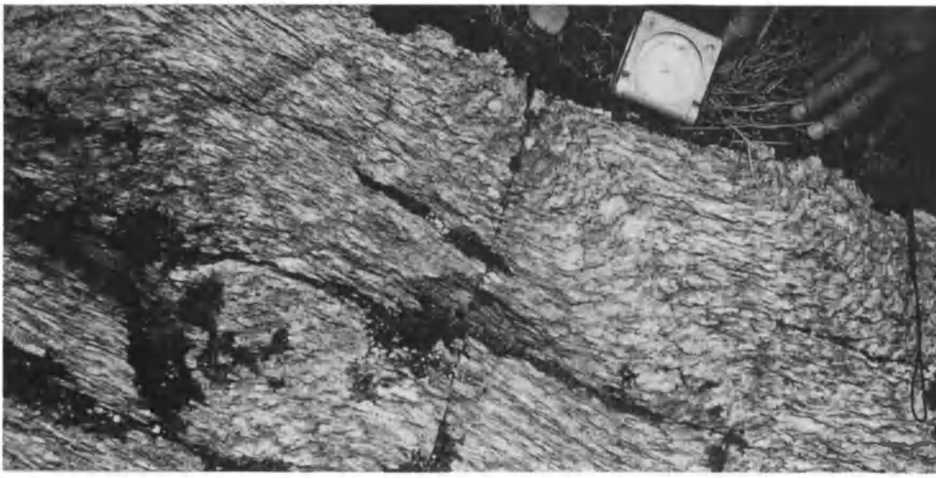


1

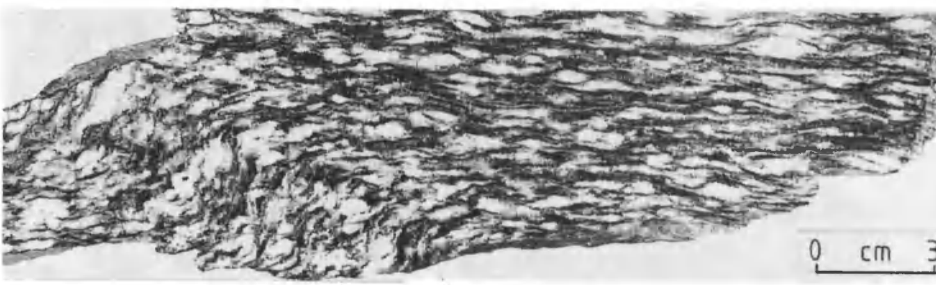


2

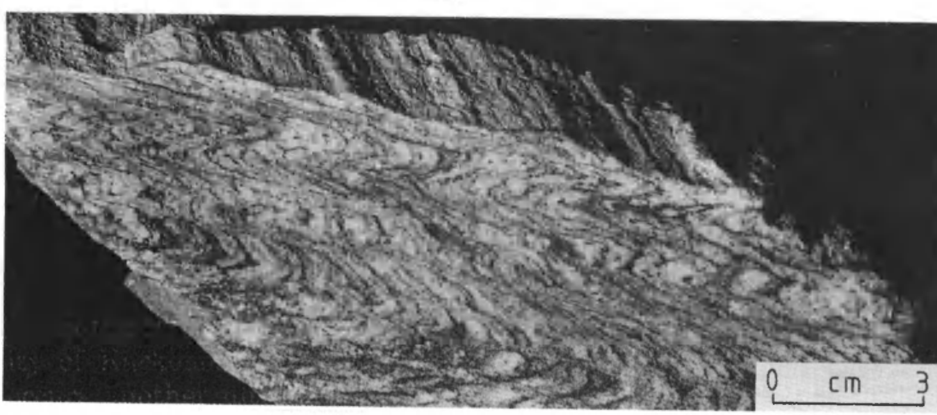
Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis



1



2



3

Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis

1

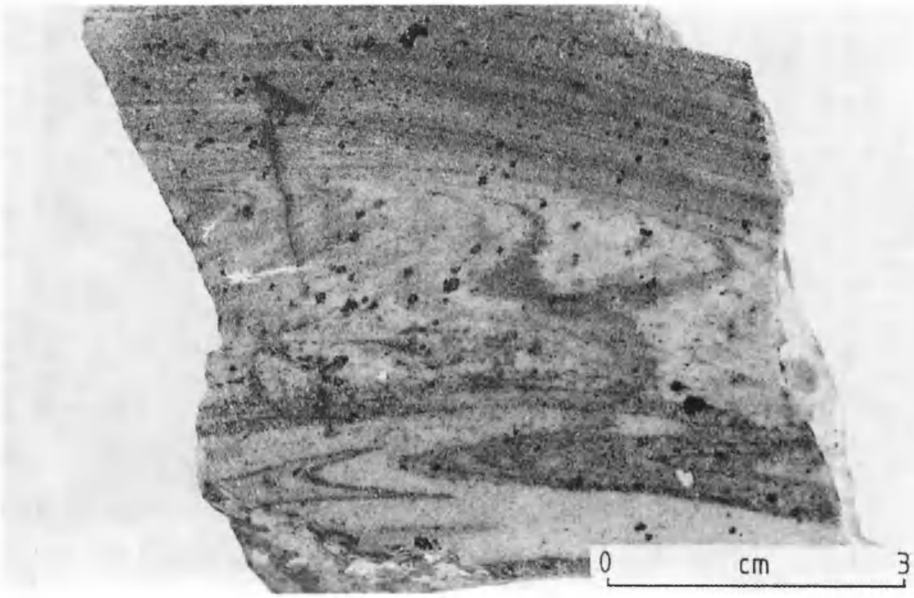
2

Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis

1

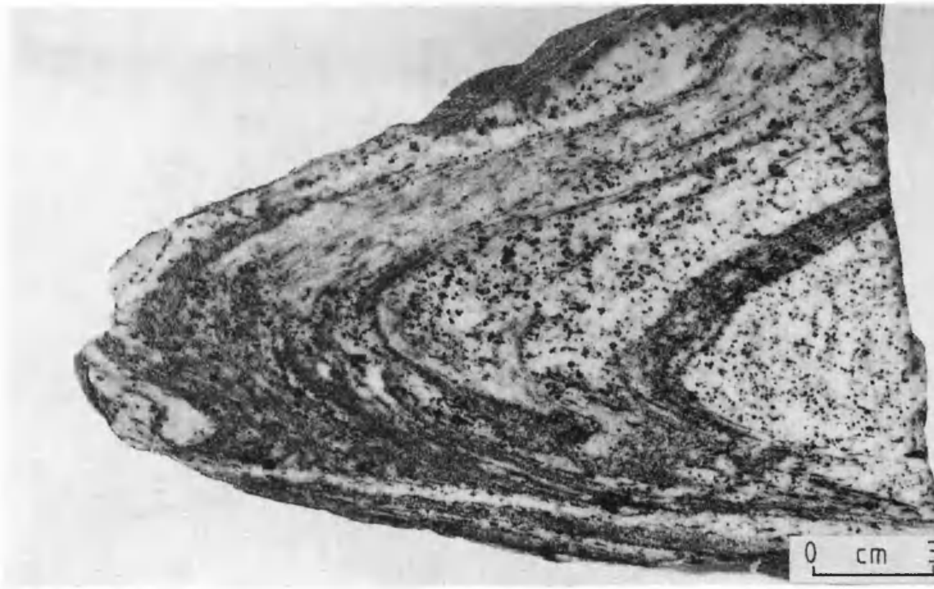
2

Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis

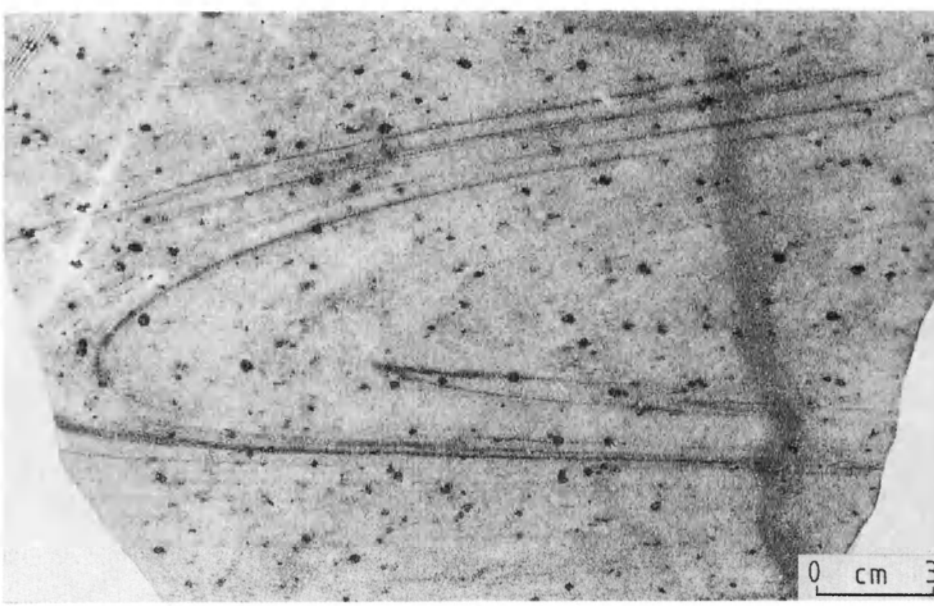


1

2

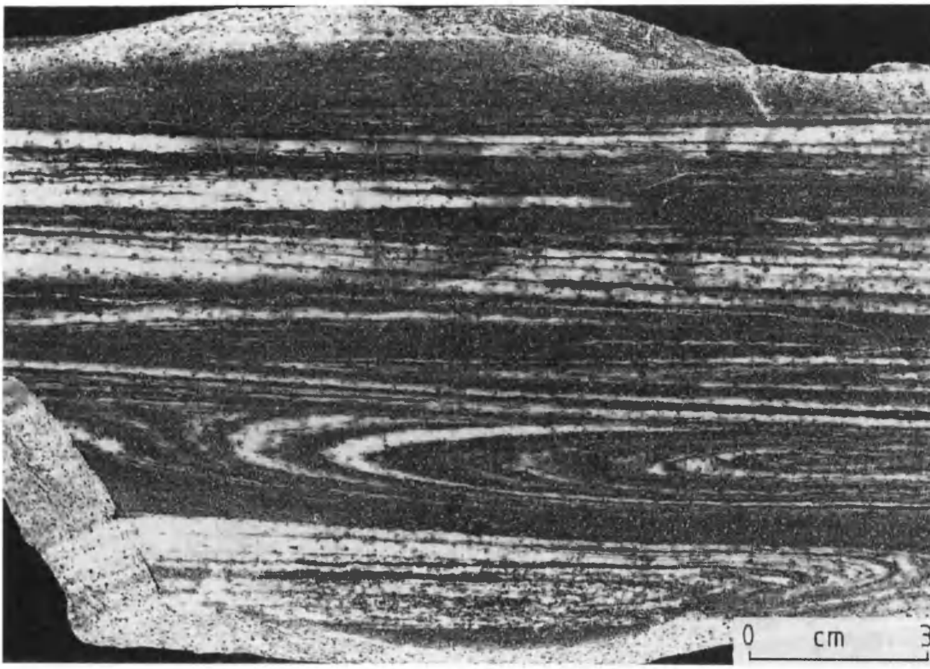


1

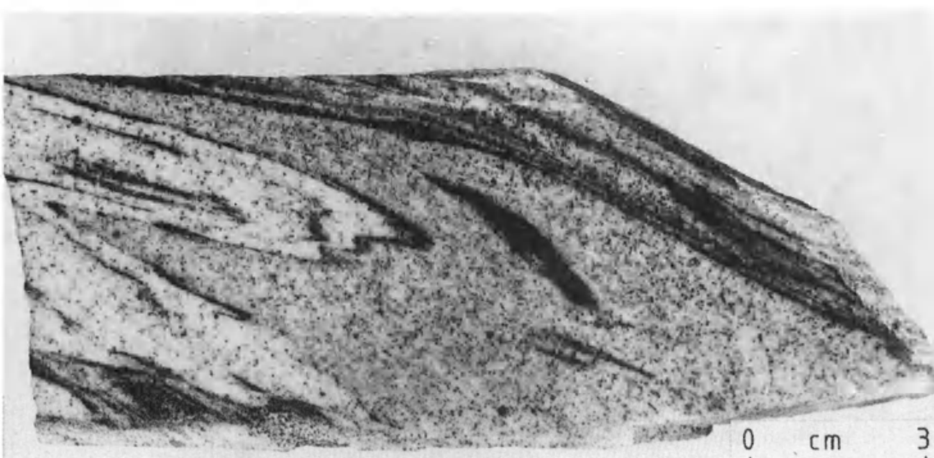


2

Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis

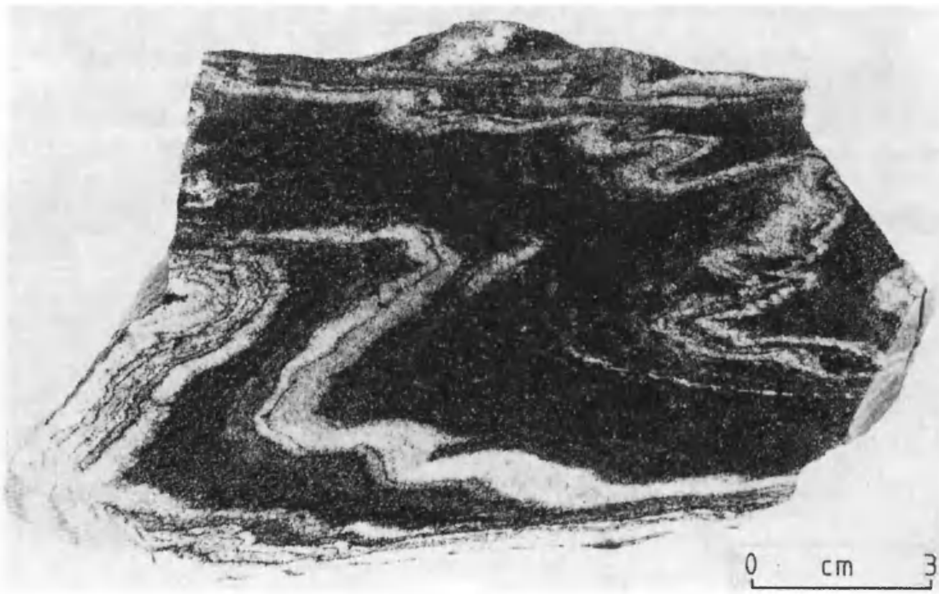


1

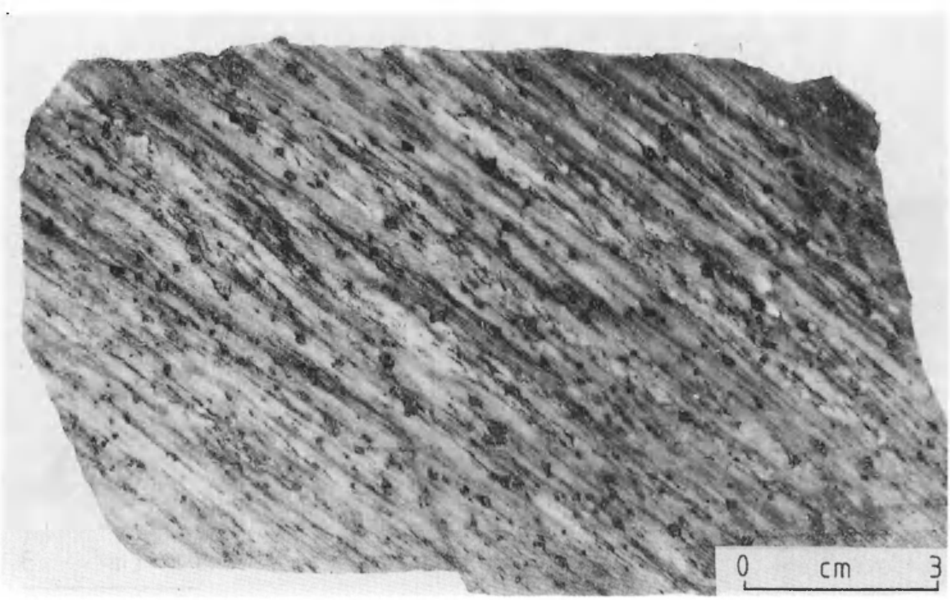


2

Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis



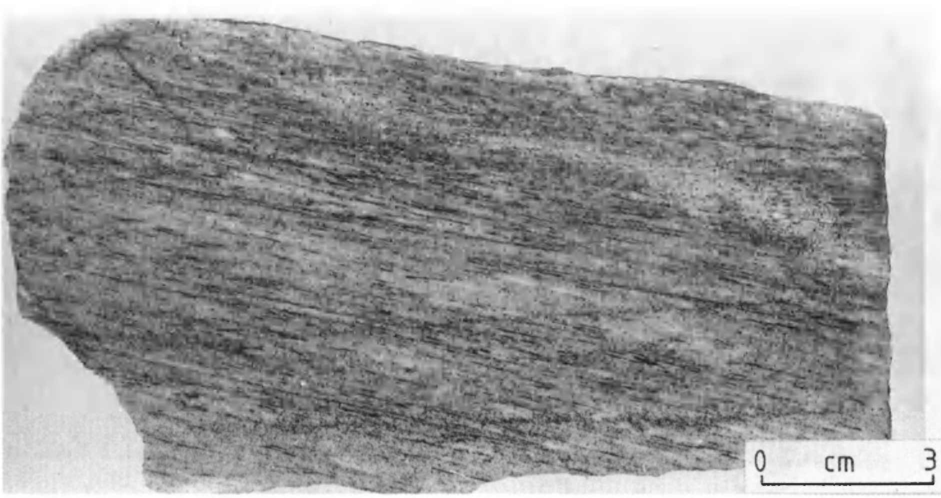
1



2

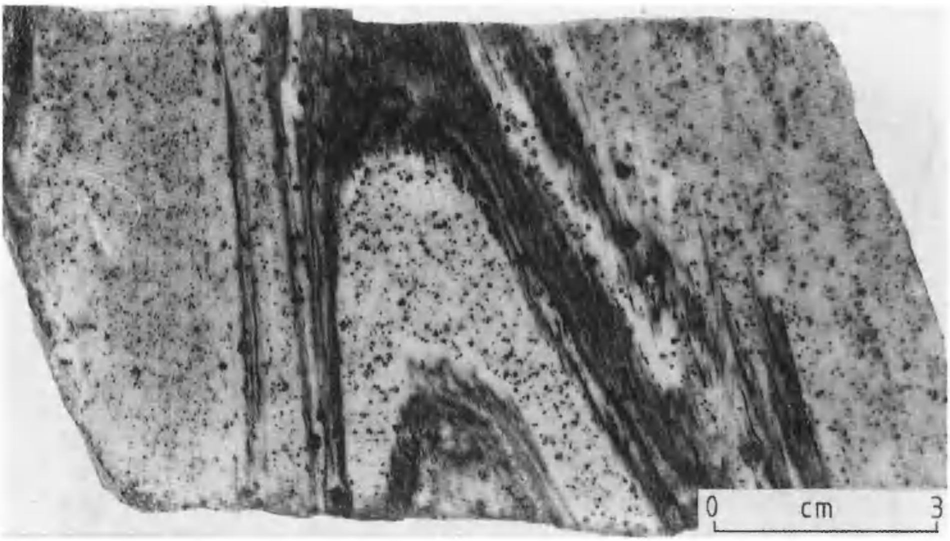
Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis

1



2

Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis

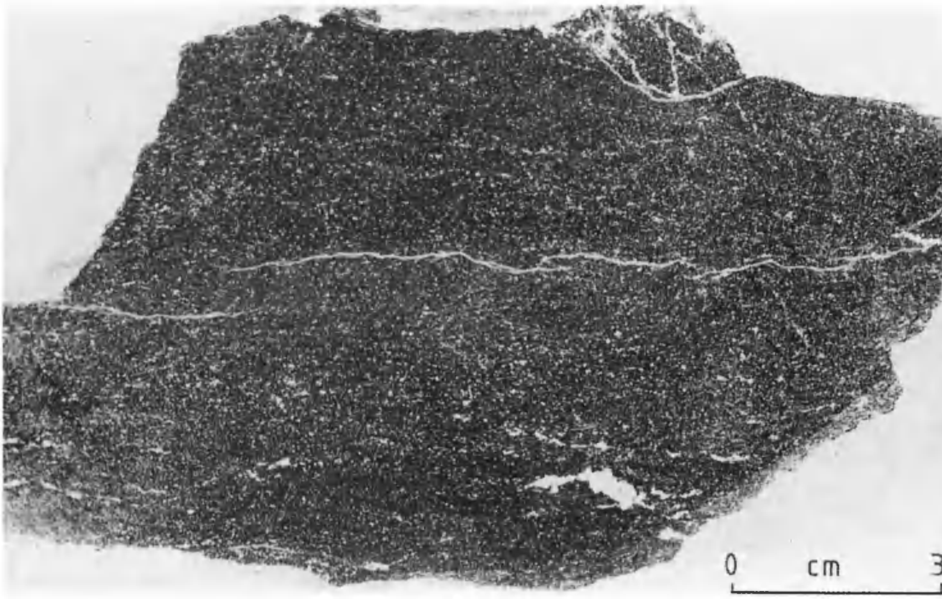


1

2

3

Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis

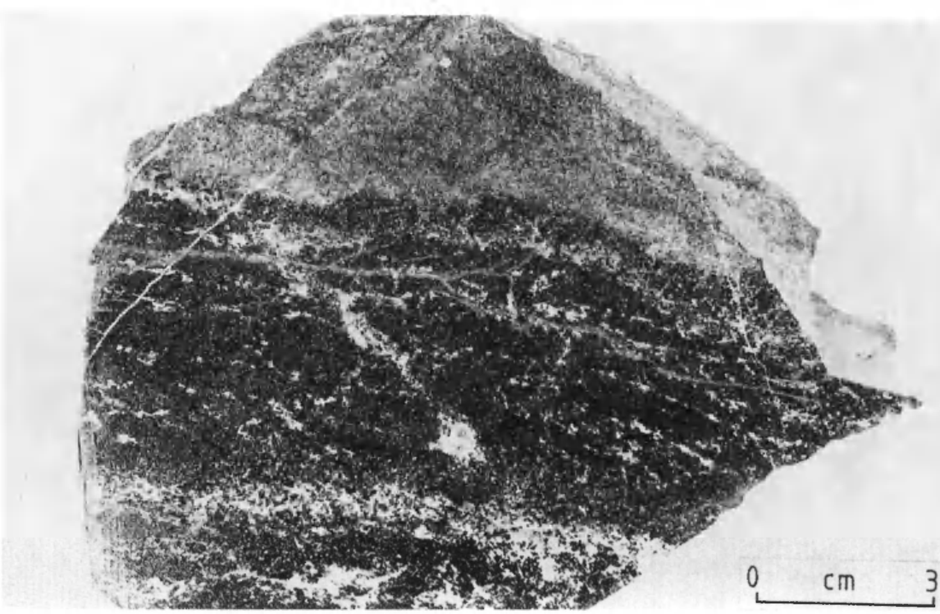


1

2

Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis

1



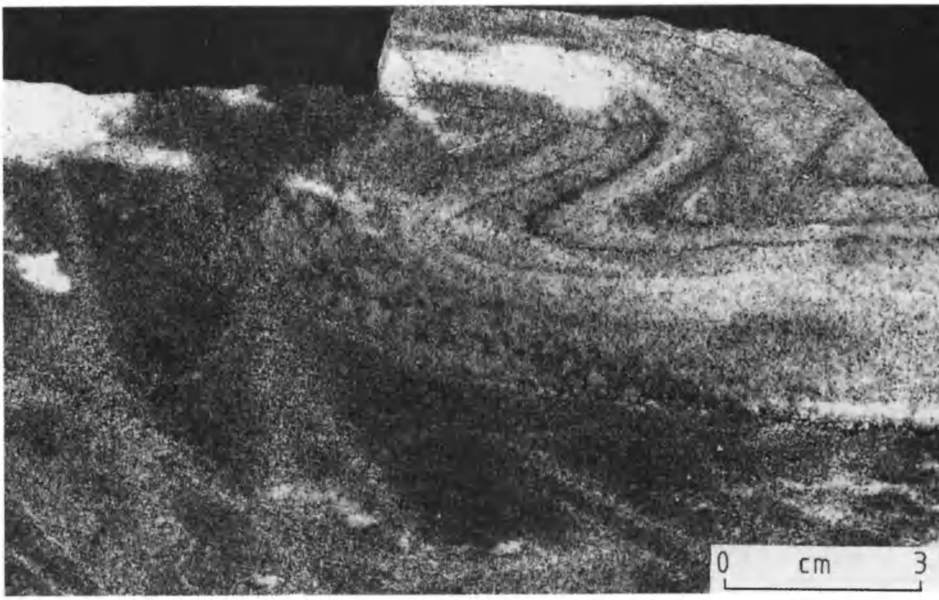
2

Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis

1

2

Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis



1

2

Marian DUMICZ – The history of eclogites in the geological evolution of the Śnieżnik crystalline complex based on mesostructural analysis