GEOLOGICKÝ ZBORNÍK — GEOLOGICA CARPATHICA, 34, 4, BRATISLAVA, AUGUST 1983, Pp. 457—482

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OUTLINE OF GEOLOGICAL-STRUCTURAL DEVELOPMENT OF THE CRYSTALLINE COMPLEX AND ENVELOPE PALAEOZOIC OF THE POVAŽSKÝ INOVEC MTS.

(Figs. 10)

Abstract: The southern block of the Považský Inovec crystalline basement was overthrust on the northern block during palaeoalpine folding. Blocks show different distribution of andalusite and sillimanite isograd in the horizon of older staurolite isograd, different types of migmatites, as well as different contents of granitoids. The blocks represent distinct structural horizons with characteristic deformations and different degree of retromorphism. Pre-alpine structures are of E-W direction; older alpine structures are of E-W, younger alpine structures of N-E direction. Crystalline basement belongs probably to the two groups: younger — Early Palaeozoic; older — perhaps even pre-Cambrian? (polymetamorphosed, polydeformed).

Резюме: Южный блок кристаллиникума горного массива Поважски Иновец был во время палеоальпийского складкообразования надвинутый на северный блок. Блоки показывают разное распределение андалузитовой и силлиманитовой изоград в ярусе старшей ставролитовой изограды, разные типы мигматитов и разное содержание гранитоидов. Блоки представляют и разные структурные горизонты с характерными деформациями и разной степенью ретроморфизма. Доальпийские структуры В-З направления; старшие альпийские структуры В-З направления, младшие альпийские структуры С-Ю. Кристаллиникум относится вероятно к двум группам: младшей — раннепалеозойской; старшей — может быть даже докембрийской? (полиметаморфизована, полидеформирована).

Introduction

Before knowledge gained by field work of J. Kamenický (1955—1958) we find only brief references on the Považský Inovec crystalline basement in literature (Štúr, 1860; Stache, 1864 ex J. Kamenický, 1956). During the First World War the crystalline basement of the Považský Inovec Mts. was mapped by Ferenczi who summarized his knowledge in few short reports, but his map was not published (Ferenczi, 1915, 1916, 1917, 1918, 1934 ex J. Kamenický, l.c.). The aim of the field geological research at the end of the fifties (J. Kamenický) was to gain map foundations for compiling of general geological map of the Považský Inovec Mts. on a 1 : 200 000 scale with explanations (J. Kamenický in Buday et al., 1962, 1963; J. Kamenický in Mahel' et al., 1962; J. Kamenický, 1959 ex Kuthan et al., 1963), which gave the first complex picture of crystalline complex and envelope Palaeozoic of the Považský Inovec Mts. as a constituent part of the

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outer arc of the core mountains in the central West Carpathians. Analysis of the tectonic structures has not been carried out in detail, and therefore, up to the present stage, the considerations on tectonics have been drawn especially from some known megastructures and orientation mesostructural measurements.

The Považský Inovec crystalline basement represents, according to J. K a m e n i c k ý (1956), a folded megaanticline with elevation in the middle, falling in the north and in the south to axial and transversal depressions respectively. He called a tectonic line at the eastern border of the mountain range characterized already by M a h e ľ (1951) Závada — Dubodiel line.

According to M a h e ľ (in M a h e ľ et al., 1967) the Považský Inovec Mts. represent a typical post-Palaeogene megaanticlinal horst elongated in the NNE-SSW direction, limited from the both sides by a system of longitudinal faults: western — Považie fault (M a h e ľ, 1951) and eastern — Závada fault (M a h e ľ, 1969).

Transversal dislocation (in the middle of the moutain range) of the WNW-ESE direction accompanied with phyllonites is considered by J. K a m e n i c k ý (in C a m b e l et al., 1961) as an alpine overthrust plane of the southern part of the crystalline complex on the northern part. M a h e ľ (l.c.) specifies this structure as a Hrádok fault. Expresiveness of this discontinuity has been verified by geophysical research too (P o l á k — K u c h a r i č, 1973).

According to J. K a m e n i c k ý (l.c.) Carboniferous and Permian at the northwestern periphery of the mountain range have a monosynclinal position, whereby from the Late Palaeozoic series of strata he mentions only Permian to be folded into the crystalline basement of the northern part of the mountain range.

M a h e ľ (in M a h e ľ et al., 1967) refers to a slight metamorphism of a part of the folded (into the crystalline basement) Mesozoic, which does not interfere to bigger depths.

Boundary of gravimetrically distinct areas: a northern (block of the Strážovské vrchy Mts.) noted for expressive negative anomalies, little differentiated, and a southern (block of the Považský Inovec Mts.) characterized prevailingly by positive anomalies, is connected by M a h e ľ (1969) with fault structure of old origin in the area of Trenčín — Bánovská kotlina basin — NE border of the Tribeč Mts. (B u d a y — D u d e k — I b r m a y e r, 1967) and he called it Jastrabie fault, which cuts of the core of the Považský Inovec Mts. on the north.

From the point of view of later information on geological structure of the crystalline basement and the West Carpathians, on the whole, from the end of the sixties and from the course of the seventies, it became necessary to complete the existing information on geological structure also in this moutain range, especially by application of structural analysis. Later knowledge given in the paper has been acquired by the author during geological mapping on a 1 : 25 000 scale, structural analysis and microscopical petrography.

Types of rocks of the northern and southern crystalline blocks

Crystalline basement of the Považský Inovec Mts. forms a constituent of the two blocks, out of which the southern block is overthrust on the northern one.

Alpine overthrust is proved by presence of envelope Upper Carboniferous and Permian of the northern block directly below the overthrust surface (Putiš, 1980). Geological structure of the Považský Inovec Mts. has been influenced decisively by alpine tectonics, what incorporation of crystalline basement into the alpine structural plan proves (Fig. 1). In the present erosive level we find in the Považský Inovec Mts. side by side crystalline basement of the two pre-alpine metamorphic horizons (Putiš, 1981, 1982 b):

Higher metamorphosed crystalline basement (sillimanite isograd, ± andalusite, ± staurolite) is found at the surface in the southern part of the mountain range (the southern block) where the following rocks are present: paragneisses (biotite, two-mica, with higher quartz contents, garnet, garnet-sillimanite, locally with staurolite, andalusite); mica-schist gneisses with porphyroblastic garnet and staurolite form the northern edge of paragneisses to which they pass gradually; amphibolites and their metatuffs; intercalations (x dm) of metaquartzites; just fragments of dark crystalline schists with graphite and graphite quartzites; migmatized paragneisses and amphibolites; late orogenic Hercynian migmatites: especially nebulites, stromatites, less ophtalmites; late orogenic Hercynian granitoids: a) unhomogeneous medium- and coarse-grained granite to granodiorite with the remnants of metamorphosed mantle of various size, with considerable contents of sillimanite — expressively prevailing type, b) leucocratic aplite-pegmatite granite with muscovite, garnets (almandine ?), sillimanite, chambers of microcline — very slightly contaminated by metamorphosed envelope (± biotite), c) homogeneous or almost homogeneous medium- to fine-grained granodiorite usually with sillimanite, d) sporadic vein penetrations of medium-grained muscovite granite with higher contents of orthoclase and secondary epidote, e) aplites, pegmatites; only locally narrow zones of mylonites and phyllonites.

Crystalline basement of the northern part of the mountain range (northern block) represents a relatively upper horizon characterized only by sporadic occurrence of granitoids (minor penetrations of aplite-pegmatite granite). This part of the crystalline basement belongs by degree of pre-alpine metamorphism to the staurolite isograd, with the local presence of postkinematic andalusite and fibrolite sillimanite younger than staurolite (Putiš, 1980, 1981, 1982 a, 1982 b).

The rocks are expressively diaphthoritized (J. Kamenický in Cambel et al., 1961; J. Kamenický in Maheľ et al., 1967), whereby from relictly preserved original rocks fine-grained biotite-muscovite mica-schist gneisses with relatively plane surfaces of S_1 metamorphic foliation with transition to paragneisses prevail; coarser-grained mica-schist gneisses with porphyroblastic garnet and staurolite (porphyroblasts of 0.5—1 cm size) with undulate S_1 surfaces show transition to mica schists, amphibolites and their metatuffs; sporadically even thicker (x 10 m) intercalations of metaquartzites; rare thin intercalations (x dm) of dark crystalline schists with graphite; migmatites of diffusive type (only sporadically with ptygmatic folds of leucosome) with transition to eye (feldspar) gneisses; sporadic aplite and pegmative veins; high share of mylonites and phyllonites with high contents of lateral-segregated quartz; vein penetrations of porphyrites (Hovorka, 1960) considered for a product of incipient alpine volcanism by this author.

Notes to lithology, progressive regional metamorphism and retrograde metamorphism (retromorphism)

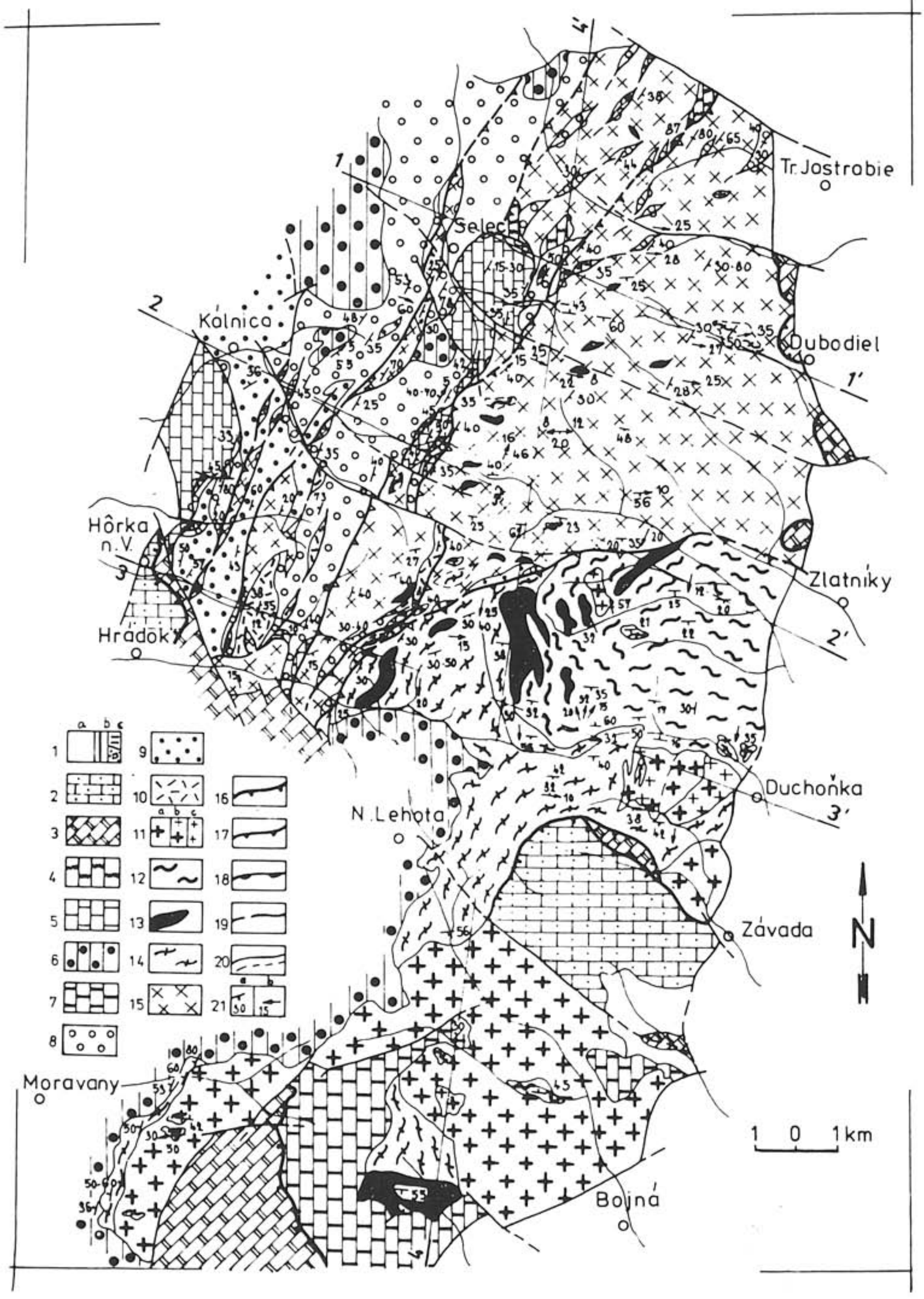
Lithology

Substantial parts of the crystalline basement of the both blocks do not show principal differences in pre-metamorphic development. Clayed-sandy and greywacke sediments with intercalations of sediments rich in quartz or in bituminous component with interbed bodies of diabases, their tuffs and tuffites were originally in question. Presence of minerals, such as: garnet — almandine, staurolite, andalusite, sillimanite, indicates an increased Al contents — components in the original sediments. Comparing the blocks the more expressive difference is shown by repeated and thicker (x m — x 10 m) intercalations of metaquartzites in uncovered horizon of the northern crystalline block coming from the part of sedimentary basin with the higher contents of sandy and quartz-sandy sediments.

Alternation (x m — x 10 m) of coarser-grained mica schist rocks (mostly with porphyroblastic staurolite) and fine-grained mica-schist gneisses to paragneisses (mostly without staurolite) are considered to be also a result of lithological (and chemical), changes in original sediments.

Dark crystalline schists with graphite and graphitic metaquartzites have been found only in fragments on paragneisses in the southern crystalline block (locality: W of Brdo; Železnica valley — NW of Krislo). In the northern crystalline block similar rocks form only rare intercalations (x dm) in diaphthoritized metamorphites (locality: Horný lom; Hrozeníkov stok).

Fig. 1. Geological-tectonic sketch-map of the crystalline rocks and envelope Palaeozoic of the Považský Inovec Mts. Compiled by Putiš (1981). *Explanations: 1 a* — Quaternary, Tertiary (undivided); 2 — Choč nappe; 3 — Krížna nappe; 4—6 — envelope Mesozoic tectonically incorporated into the northern crystalline block; 4 — Lower Jurassic (mainly conglomerates, sandy limestones, shales); 5 — Middle Triassic (guttenstein limestones and dolomites); 6 — Lower Triassic (quartzites) — traced only as a basal part of the main mass of Mesozoic envelope at the western border of the both crystalline blocks; 7 — undivided envelope Mesozoic of the southern block (mostly quartzites, limestones, dolomites, shales); 8—10 — envelope Palaeozoic of the northern crystalline block (rocks described in the text): 8 — Upper Permian; 9 — Upper Carboniferous; 10 — Devonian — Lower Carboniferous?; 11—15 — crystalline basement: 11 a — unhomogeneous (sporadically almost homogeneous) granite up to granodiorite, the so-called hybrid type; 11 b — leucocratic aplitic-pegmatitic granite; 11 c — aplites, pegmatites; 12 — migmatites; 13 — amphibolites and their metatuffs; 14 — paragneisses, mica-schist gneisses up to mica schists; 15 — intensively diaphthoritized crystalline basement (paragneisses up to mica schists, migmatites, amphibolites); 16 — shift planes of Krížna and Choč nappes; 17 — important thrust-overthrust planes; 18 — thrust planes; 19 — faults; 20 — geological borders; 21 — planar and linear mesostructural elements; 1—1′ — line of geological profile.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Progressive regional metamorphism

In the block of the Považský Inovec crystalline basement a process of stages of development of progressive regional metamorphism on the basis of crystallization succession of the present index minerals (garnet — almandine, staurolite, andalusite, sillimanite) and their relation to S_1 planes of metamorphic foliation has been ascertained. In the metamorphic development of the both blocks the conditions of amphibolite facies of Barrow type have been reached, but with certain differences (Putiš, l.c.).

Metamorphites of an exposed horizon of the northern crystalline block as as whole belong to the staurolite isograd, which is penetrated by later andalusite isograd (limited occurrence of fibrolitic sillimanite). On S_1 planes the following (older) mineral association: quartz, plagioclase, muscovite, biotite, garnet — almandine, staurolite, is oriented. To younger mineral association be-

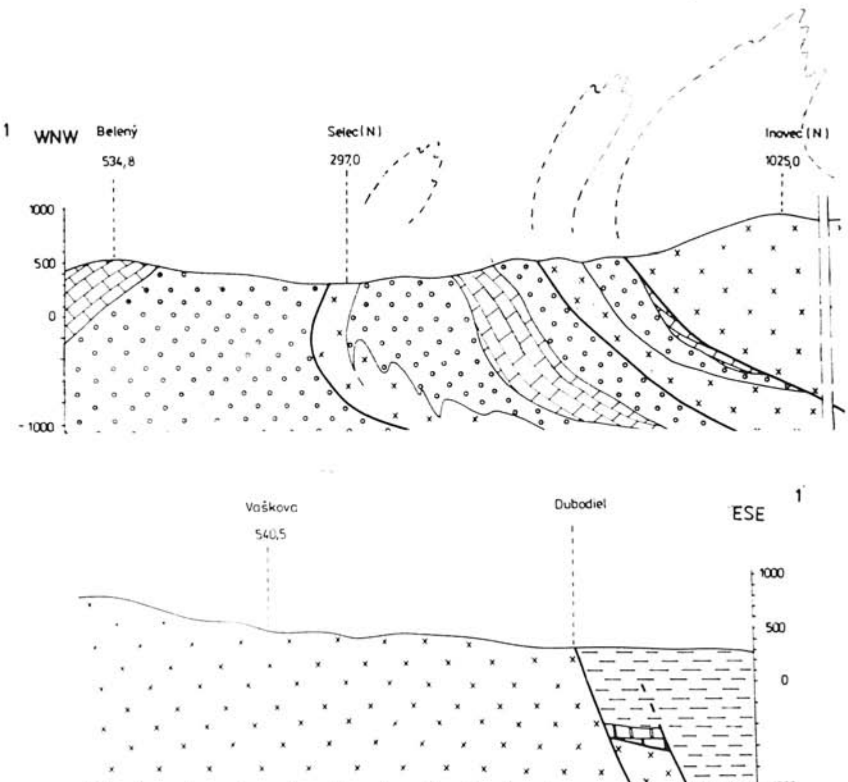
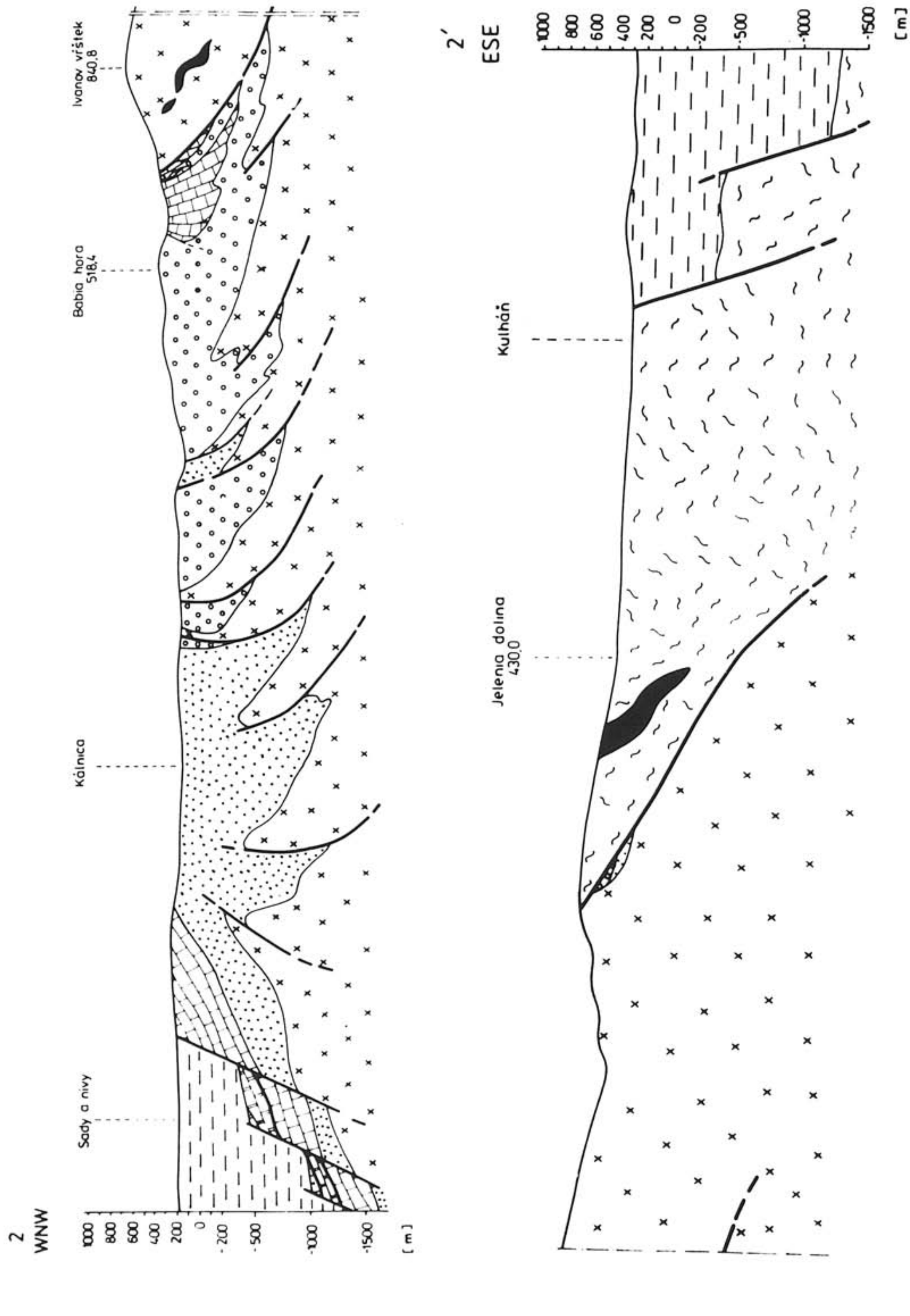


Fig. 2—5. Geological profiles. *Explanations:* 1 b — undivided Mesozoic covered by Quaternary; 1 c — Quaternory, Tertiary (undivided); 2 — Choč nappe; 3 — Krížna nappe; 5 — undivided envelope Mesozoic of the both crystalline blocks; 8—10 envelope Palaeozoic of the nortern crystalline block with marking of magmatite bodies mentioned in the text; 11—15 — crystalline basement (of the both blocks); 16—20 — according to geologic-tectonic sketch.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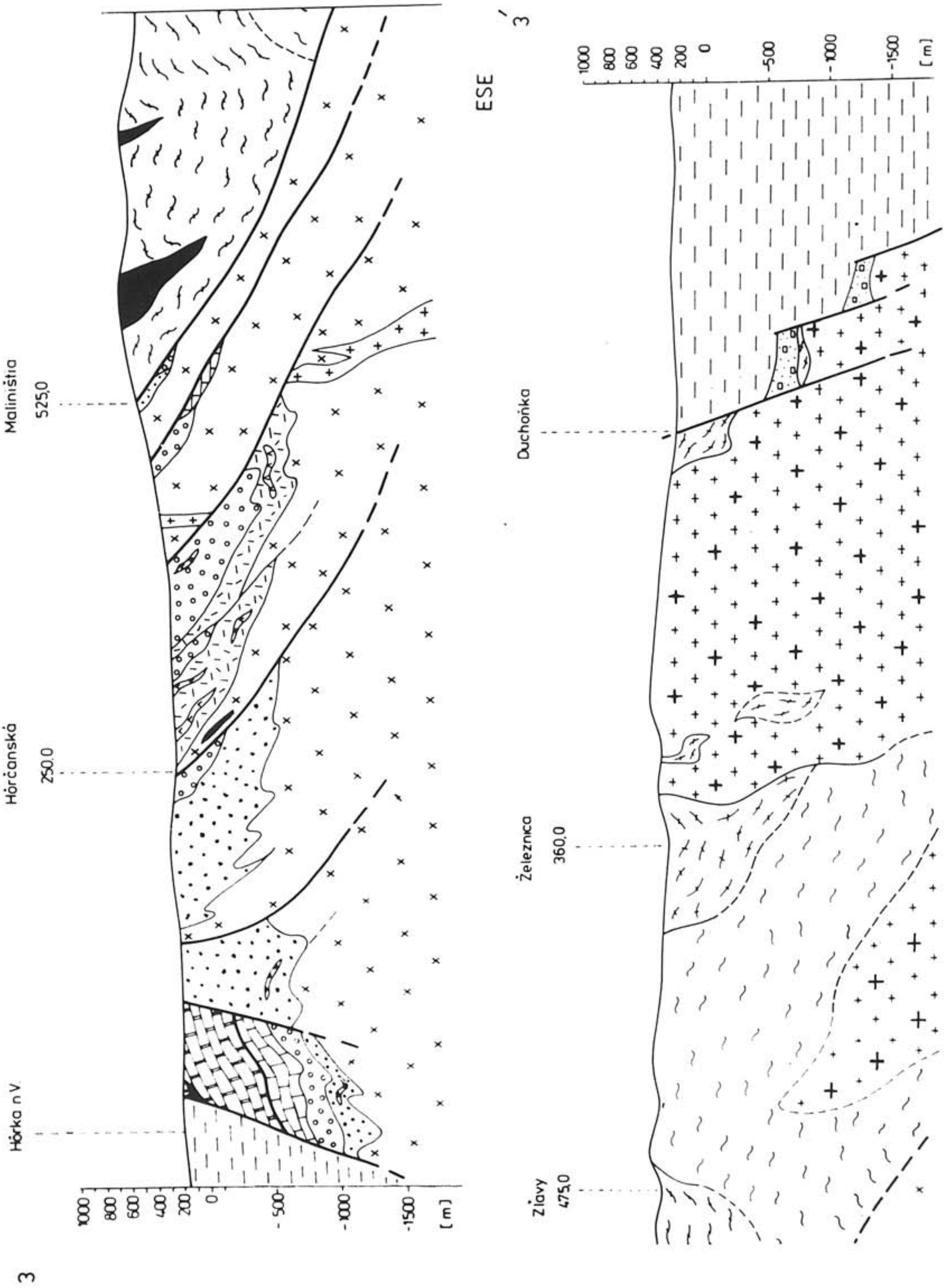
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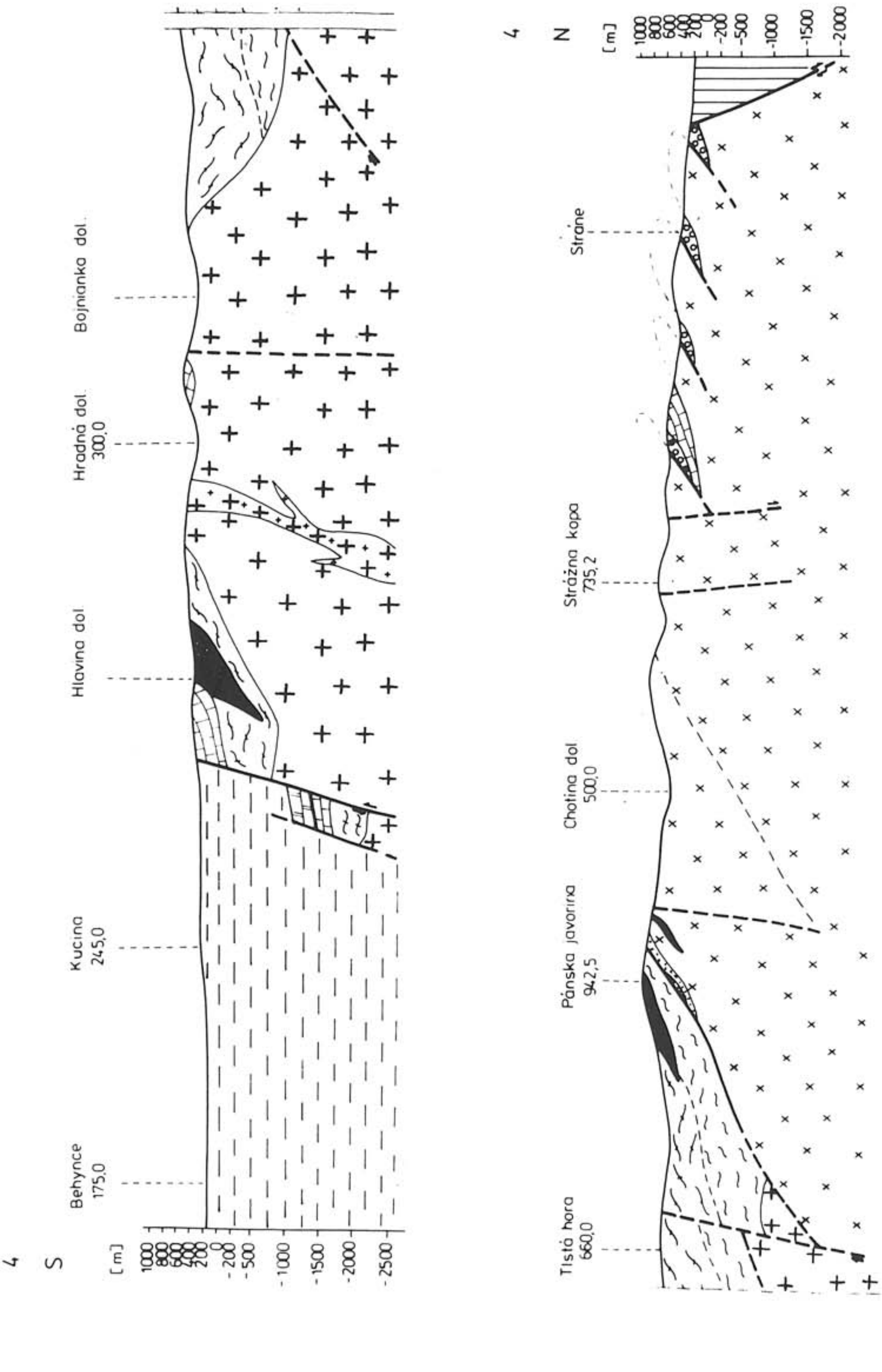
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Chotina dol.
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long: postkinematic porphyroblastic andalusite (it closes S_1 planes with a corresponding older mineral association), fibrolitic sillimanite (on biotite and andalusite), porphyroblastic muscovite$_2$ (grows cross to S_1). Especially selective mobilization of quartz-feldspar leucosome (andalusite is closed by quartz-feldspar leucosome), feldspathization and by diffusion — metasomatic processes in paragneisses to mica schists link to the reached conditions mainly of andalusite isograd.

Metamorphites of the southern crystalline block as a whole belong to sillimanite isograd, staurolite (in mica-schist gneisses) and andalusite are locally present. In paragneisses the following mineral association is present: quartz, plagioclase, orthoclase, ± coarse-crystalline sillimanite, fibrolitic sillimanite, ± muscovite, ± staurolite, ± andalusite; fibrolitic sillimanite is usually present on biotite, muscovite and andalusite.

Reaching of sillimanite isograd in the southern crystalline block, similarly as in the northern one, is considered only for metamorphic event in the process of metamorphic development of the crystalline complex. Rock association: mica-schist gneisses — paragneisses — stromatitic migmatites — unhomogeneous granites to granodiorites (with palimpsests of S_1 planes) — leucocratic aplite-pegmatite granites occur in this horizon not by chance.

In the southern crystalline block under the conditions of sillimanite isograd migmatitization begins with local anatectic mobilization of quartz-feldspar leucosome. In deeper parts of supracrustal series a partial anatexis of greater extent evidently occurs during origin of mobile palingenetic melt which being already partly differentiated had risen to higher horizons of supracrustal series during origin of stromatitic migmatites. Migmatites of the southern block are genetically connected with formation of granites of palingenetic-anatectic origin. Borders between paragneisses, migmatites and granites (granodiorites) are not sharp. Intensive granitization in the overthrust southern block is comprehended as a consequence of high-degree metamorphism in deeper horizons of the crystalline complex (considerable sillimanite contents in migmatites, unhomogeneous granites and granodiorites). Ascent ("intrusion") of palingenetic granitoids caused a raise of thermal gradient in the upper horizons of the crystalline complex with mica-schist gneisses to paragneisses, migmatitized paragneisses, where the reached conditions of the sillimanite isograd are included, as a rule, only in middle-degree metamorphism (exposed horizon of the southern crystalline block).

Any essential differences, as far as occurrence of index metamorphic minerals, succession of their crystallization relation to S_1 planes or to the type of metamorphism are concerned, do not result from the analysis of development of progressive regional metamorphism of the both crystalline blocks. Original regional metamorphism of Barrov type has reached in the both crystalline blocks P-T conditions of the staurolite isograd, i.e. facies of almandinic amphibolites, staurolite-almandine subfacies (Winkler, 1967), medium-degree metamorphism (Winkler, 1974), probably only of low-pressure type (Miyashiro, 1973), as kyanite has not been found. Relatively newer metamorphic event in conditions of andalusite and sillimanite isograd indicates a higher geothermal gradient but at roughly same or lower pressures. We suppose that at older metamorphic event maximum of the P-T conditions has been reached at the temperature of about 550 °C and pressure of 500 MPa (5 kb). At newer metamorphic event the conditions of anatectic minimum have been reached at the temperature of about 650 °C and pressure of 450 MPa (4.5 kb); maximum conditions at the temperature of about 700 °C and pressure over 400 MPa (4 kb) (according to model graphs of the P-T conditions of metamorphism of the similar rock types — W i n k l e r, l.c.).

Retrograde metamorphism (retromorphism)

Presence of diaphthoritic rocks in the crystalline basement of the northern part of the mountain range has been know for a long time (J. K a m e n i c k ý, l.c.), but the question of the relation of diaphthoresis to the tectonic structures of the crystalline complex has not been solved.

In the Považský Inovec crystalline basement two types of retromorphism may be distinguished:

1. Type of synkinematic retrograde metamorphism of regional character applied in uncovered horizon of the northern crystalline block;

2. Type of dynamic retromorphism connected with intensive mylonitization to phyllonitization of rocks with the following recrystallization and neomineralization joint to an overthrust plane (E-W direction) af the southern block, on the northern one as well as on the other important alpine thrust or thrust-overthrust planes of the prevailing NNE-SSW direction.

During retromorphism metamorphic conditions of the lowest subfacies of the green schist facies have not been exceeded as indicated by mineral association of recrystallization and neomineralization: quartz, sericite, chlorite, ± muscovite, albite, minerals of epidote-zoisite group, ± actinolite.

Besides mechanical manifestations of penetrative movement on S_1 planes, the following characteristic mineral changes are observed: local recrystallization of quartz; feldspars are partly to totally sericitized, albitized; biotite partly to totally chloritized, baueritized, usually with inclusions of rutile, skeletal ilmenite, needlelike sagenite; amphiboles are most frequently pushed back by chlorite, minerals of epidote-zoisite group, calcite; garnets intensively chloritized; staurolite and andalusite sericitized; tourmaline, Fe oxides, veinlets and lenticles of lateral segregated quartz are usually present.

Owing to application of penetrative movement on S_1 planes during retromorphism, expressive microstructural manifestations of deformations connected with retromorphism are observed in the affected rocks and their minerals: transverse undulatory extinction of quartz against its orientation on S_1 planes; cut of quartz grains, reorientation (to recrystallization) according to younger system of planes representing usually microcleavage of axial plane of microfolds; ruptures, flexure deformation, translation often according to lamellae up to oriented sericite mass are observed in feldspars; flexure and rupture deformations are frequent also in garnet, staurolite and andalusite; biotite and muscovite are folded in detail in the hinge parts of microfolds, often segmented by younger cleavage planes or split and broken; interruption of microfolds in hinge parts leads to gradual transposition of the corresponding folded planes to a newer system of cleavage planes; relict parts of older microfolds are found in lithons between the newer cleavage planes.

Thus diaphthorites from the Považský Inovec Mts. represent B-tectonites with transition to S-tectonites (P u t i š, 1981).

Retrograde biotite alteration (chloritization) has been found also in connection with paragneiss migmatitization in the southern crystalline block on the contact of palaeosome (biotite) and quartz-feldspar leucosome neosome), and especially in individual biotite lamellae, eventually garnet grains in the middle of neosome, whereby the rocks of meso- and microdomain do not bear any marks of mechanical destruction. Such type of retromorphism can be compared with retromorphism linking to the final part of progressive regional metamorphism (cf. A n g e l, 1965).

The most evident demonstriation of retromorphism is in the northern crystalline block where three regions with different intensity of retromorphism, as well as deformations can be distinguished. These regions represent diverse structural horizons of the crystalline basement with different effects (i.e. differentiated representation of deformations) of the individual stages of deformation:

1st region — includes the northern and western parts of the crystalline basement;

2nd region — includes the central, eastern and southern parts of the crystalline basement;

3rd region — is limited to overthrust zone of southern block on the northern one.

The first region is characteristic by a very strong deformation and, at the same time, by the most intensive retromorphism (the total biotite and garnet chloritization), as a result of deformation stage whose structures of general NNE-EEW direction (in megascale in half-arc N-S to ENE-WSW) are dominating here and they totally liquidate the older deformations. Common refolding of the crystalline basement with the Palaeozoic-Mesozoic envelope can be observed directly in some exposures. This region represents the uppermost palaeoalpine structural horizon of the crystalline basement.

The second region is characteristic by the roughly equivalent representation of older strutures of general E-W direction and superposed younger structures of N-S to NE-SW direction. In this region the resultant degree of retromorphism is evidently lower than in the previous region. The rocks do not bear such high effect of mechanical overwork and recrystallization (biotite and garnet only partly or slightly chloritized). The original rocks and position of S_1 planes are mostly well identifiable. S_1 plianes have a double position here: 1. E-W (with slight deviations) — in mesodomains with monoclinal position of S_1 planes; in the limbs of relict macrofolds (F_1) or mesofolds (F_{1-2}); 2. NE-SW to N-S — in the limbs of F_2 folds which already do not bear the marks of younger refolding as the F_{1-2} folds. Change of position of S_1 planes in the process of superposed F_{1-2} and F_2 folding is observable in continuous succession of exposures. This region represents a deeper palaeoalpine structural horizon of the crystalline basement in comparison with the previous region.

In the third region cataclasis dominates over recrystallization and neomineralization on penentrative S_2 planes of E-W direction.

From the analysis of relation of retromorphism intensity to the tectonic structures of the crystalline basement it comes out that dominating retromorphism refers to the last palaeoalpine deformation stage (D_3 — F_2, S_3) in the uppermost palaeoalpine structural horizon. In deeper palaeoalpine structural horizon with slighter influence of D_3 deformation stage the retromorphism is weaker as well. Inward the Carpathian arc and in direction to depth, influence of D_3

deformation stage falls simultaneously with influence of alpine retromorphism. The southern crystalline block represents the innermost part of the Inovec crystalline complex only with local (nonpenetrative) occurrences of deformations of D_3 deformation stage type. Retromorphism is here also weak and local.

While dependance of retromorphism on alpine general N-S and E-W structures is clear, structural record of older (pre-alpine) retromorphism overworked during the later superposed alpine deformation stages remains questionable. The fact is that a considerable part of rocks of pebbles from the Upper Carboniferous (J. Kamenický, 1958) and Permian (Putiš, 1981) conglomerates has the marks of distinct retromorphism and deformation often only in slightly oriented groundmass of these conglomerates.

In the northern crystalline block the N-S structures pass from the crystalline basement to Palaeozoic-Mesozoic envelope and deformations can be hardly found there in connection with pre-alpine retromorphism (diaphthoresis). From the E-W structures the F_{1-2} mesofolds (with B-axis of approximately E-W direction) the types of which have not been ascertained in Palaeozoic-Mesozoic envelope (tectonically included in the crystalline complex) where E-W structures are of inferior importance (local crenulation cleavage) have not quite clear relation to the alpine stages of deformation. At the same time it is certain that F_{1-2} mesofolds do not belong to D_1 and very probably not even to D_2 deformation stage and they are relic of D_{1-2} deformation stage(?) connected with the pre-alpine diaphthoresis.

From the record of retromorphism in the Považský Inovec crystalline basement it results that retromorphism is of polystage character here (it is connected with D_1 ?, D_{1-2}, D_2, D_3 stages of deformation), whereby the most clear structural record of retromorphism was left by palaeoalpine D_2 and D_3 stages of deformation.

Envelope Palaeozoic

Envelope Palaeozoic of the Považský Inovec Mts. has three lithostratigraphic units of the following age: Permian (Štúr, 1860 ex Mahel, 1950); Carboniferous probably Upper (Mahel, 1950, 1951; J. Kamenický, 1956, 1958); Devonian — Lower Carboniferous? (Putiš in Mahel et al., 1979; Putiš, 1981) which are connected exclusively with the northern crystalline block. All three units of the envelope Palaeozoic (sporadically also with a part of envelope Mesozoic) are tectonically incorporated in the common diaphthoritized crystalline basis of the northern block, i.e. they are folded into the crystalline complex or they are wedged under the thrust or thrust-overthrust plane of the crystalline complex.

Sediments mostly of the Upper Permian (according to palynological analysis: Planderová, 1977, es 1978 ex Vozárová – Vozár, 1978) represent a very varied mixture of rocks in this mountain range: sandstones, arkoses, quartz-sandy conglomerates to conglomerate quartzites, greywackes, varicoloured (green, red, violet, grey) shales, polymict conglomerates. Interbed palaeorhyolite bodies with accompanying tuffs form their component part (they are sporadic on the surfaces). Body transversally cut by Hôrčanská dolina valley near the tectonic contact of Permian and the crystalline complex may serve as an example. Thickness of effusion is about 15 m, observable lenght is about 120 m (Putiš, 1981).

Carboniferous, probably the Upper (according to the palynological analysis: Čorná — L. Kamenický, 1976), represents lithologically dark-grey flyschoid series of strata with alternation of dark-grey clayey and clay-sandy shales, arkosic and greywacke sandstones. Dark-grey to black bituminous intercalations are bound especially to clayey up to sandy-clayey shales (laminated). Irregular positions of polymict conglomerates, similarly as in the Permian, contain rich pebble to fragmental material of magmatic, metamorphic and sedimentary rocks and their minerals. Only sporadic minor bodies of albite-epidotic amphibolites without accompanying tuff material (NW of Kálnica) form a component part of the sedimentary complex. Originally they were vein penetrations probably of amphibolic diorites. Vozár (1975) considers about possibility of belonging of this sedimentary complex, as well as overlying Permian (Novanská dolina valley) to the Choč nappe. As counter-arguments may serve: 1. geological position — Palaeozoic series of strata lie directly on the crystalline basement (not on Mesozoic of the Krížna nappe), they are folded and sliced together, in addition, they are dynamometamorphized on the contact with the crystalline basement; overlying rocks on the Palaeozoic sedimentary complex in the region of Novanská and Kočovská dolina valleys are formed by the Lower Triassic quartzites of envelope and not by Mesozoic of the Choč nappe; 2. pebble contents of underlying crystalline basement in conglomerates of the Upper Carboniferous and Permian; 3. Carboniferous sedimentary complex (considered for the Choč nappe) never lies in nappe position on the present envelope Permian of the verrucano type.

Newly distinguished volcanic-sedimentary complex (Devonian — Lower Carboniferous ?) with metadiabases, green and red-violet tuffs, tuffites, mostly of metamorphic character of "green schists" with intercalations of very fine-grained quartritic sediments (silicites ?) (Putiš, l.c.) has not, for the time being, age determined palynologically.

Palaeozoic envelope as a whole shows a uniform (alpine) structural plan of dominating structural direction NNE-SSW. Structures of underlying crystalline basement (intensively mylonitized to phyllonitized) are fully subordinated to this most expressive direction of structure in the northwestern part of the mountain range, whereby the older structural elements are totally overworked and covered by dominating structures of NNE-SSW direction.

Succession of deformation stages in the crystalline basement

The northern crystalline block

D_1 stage of deformation (S_1, F_1) is connected with the pre-alpine progressive regional metamorphism of the crystalline complex during the origin of S_1 metamorphic foliation. We suppose that refolded (during F_{1-2} and F_2 folding) relictly preserved limbs, hinges and cores of macrofolds (with B-axis E-W) belonged originally to F_1 (D_1) macrofolds. In macrodomains with nonpenetrative development of the F_{1-2} and F_2 folds the S_1 planes have E-W direction and in mesodomain monoclinal position.

D_{1-2} (temporally between D_1 and D_2) stage of deformation (F_{1-2}, $\pm$ S_{1-2}) is connected with pre-alpine retromorphism (diophthoresis) in the course of which a partial rearrangement of D_1 structures occurred while preserving the original E-W direction. It is very probable that F_{1-2} mesofolds with B-axis of general E-W direction belong to the structural elements of D_{1-2} deformation stage. F_{1-2} folds originated by superposed, nearly conform refolding of F_1 macrofolds (planes S_1), and their hinges (of x m size) are relictly preserved. Overfolds to inclined folds (with axial plane inclined to the S) are prevailing in the scale of inclined to recumbent F_{1-2} folds. The typical feature of F_{1-2} folding is its disharmonic character conditioned by alternation of the competent rocks (metaquartzites, quartzitic gneisses) and less competent rocks (mica schists, micaschist gneisses, paragneisses, migmatites). Competent rocks are folded to similar and concentric folds, less competent ones are folded in detail from cm to mm folds mostly with well developed cleavage of the S_{1-2} axial plane. Hinge parts of the F_{1-2} folds are usually expressed by secreted lenticles of segregated quartz.

D_2 deformation stage (S_2) is connected with alpine dynamic retromorphism, mylonitization and phyllonitization of the crystalline basement according to shear S_2 planes during overthrust of the southern block on the northern one with formation of mylonite and phyllonite zones of E-W direction. S_2 planes are penetrative only in these zones. S_2 planes have a milder dip (O — 35° to the S) than the S_{1-2} planes.

D_3 deformation stage (F_2, S_3) includes cross (according to direction of structures D_1 — D_2) folding to slicing in NNE-SSW direction (with deviation up to N-S direction or ENE-WSW). In this way structures independent by its direction on the previous deformation stages were formed. In this direction the folding of Palaeozoic-Mesozoic envelope into the crystalline basement occurred in numerous narrow synclines. The next feature of this deformation stage is its sliced structure especially of the western border of the northern crystalline block in which the region of envelope Palaeozoic with part of envelope Mesozoic (Triassic, Lower Jurassic — Lias) is incorporated. In macroscale it is expressed by a system of subparallel thrust planes, especially distinct by bands of subjacent crystalline basement in the middle of envelope Palaeozoic (or the other way round). The most expressive is Hrádok — Selec thrust plane (Putiš, 1980) observable on the surface to more than 13 km distance.

F_2 folds with B-axis of main NNE-SSW direction (with axial plane inclined to the E, as a rule) are penetrative in mesodomain just in the northernmost part of the northern block, in the midde and southern parts they are penetrative only in macrodomain. The most frequent type of F_2 folds are conjugate kinks and kink folds with axial plane of changeable direction of dip and dip angle. B-axes are, as a rule, plunging mostly to the S.

F_2 folds are usually accompanied with S_3 planes being penetrative in domain only near the more important thrust planes (in the western part of the northern block), where they have a character of slip cleavage. The main feature of S_3 planes is expressive destruction of the crystalline basement (mylonitization, phyllonitization) connected with movement on these planes westward.

In deeper structural horizons of the envelope Palaeozoic the S_3 planes of thrusts of subjacent crystalline basement have a dip of 35 — 45° to the ESE (Hrádocká and Hôrčanská dolina valleys), they are erected in the higher horizons (Novanská dolina valley), and at last they have an opposite direction of dip, i.e. to the WNW at angle of 60 — 85° (north of Prostredná dolina valley; Selec). The eastward movement in structures of the upper parts of envelope Palaezoic and especially Mesozoic is evident also from the thrust of envelope Mesozoic on the basis of the Middle Triassic limestones and dolomites through envelope Lower Triassic quartzites, sporadically up to the Upper Carboniferous of envelope Palaeozoic (Kočovská dolina valley).

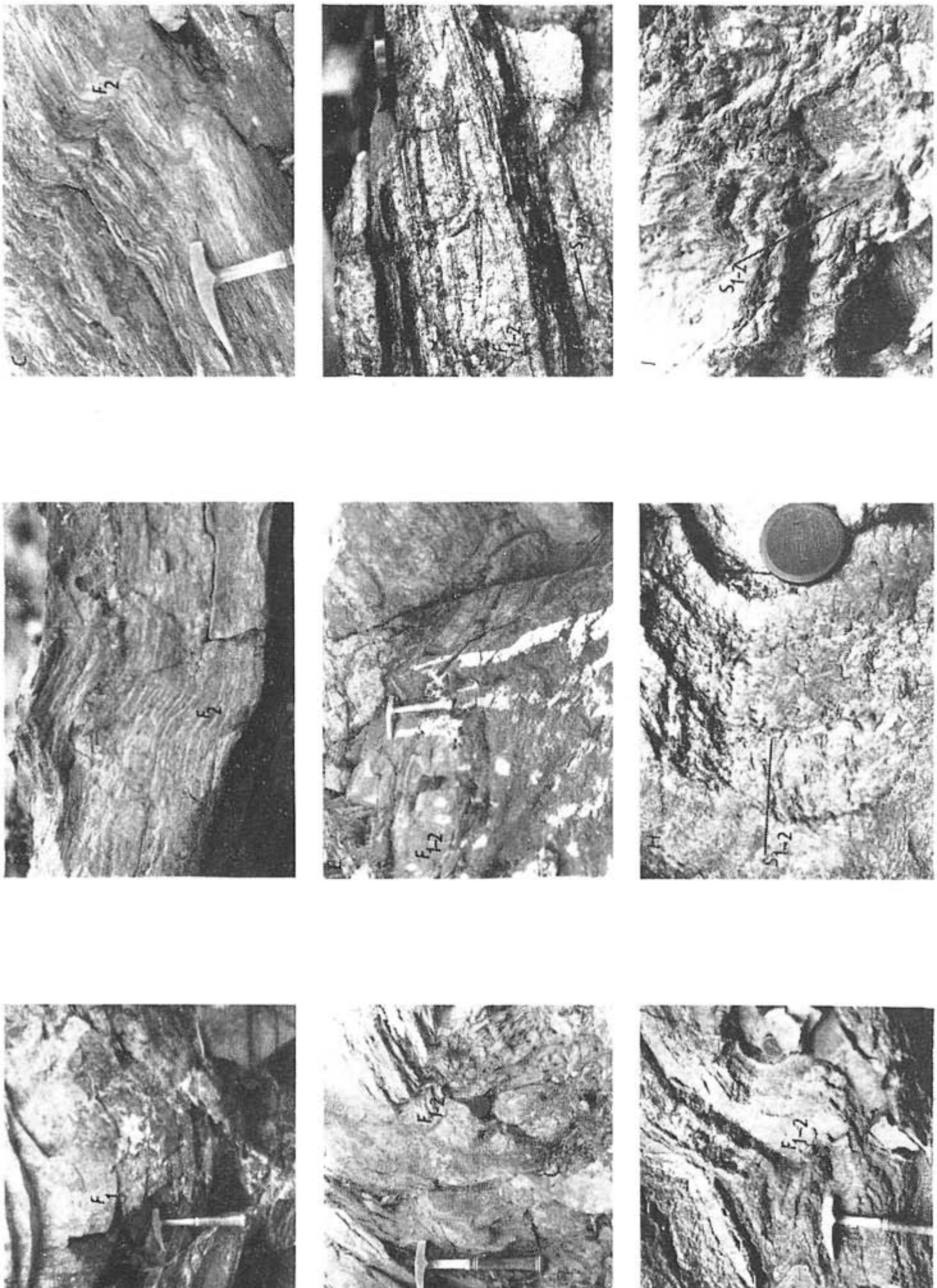
D_4 stage of deformation is typical by the above-described erection of structures of D_3 deformation stage up to opposite orientation of the movement on these or newer structures (thrust, thrust-overthrust planes).

D_5 stage of deformation is derived in megascale from half-arc course of macrostructures of D_3 and D_4 stages of deformation in accordance with course of the Carpathian arc (from N-S up to ENE-WSW direction).

The southern crystalline block

D_1 stage of deformation (S_1, F_1, $\pm S'_1$) is connected with the progressive regional metamorphism during formation of S_1 metamorphic foliation and synmetamorphic minor F_1 folds and microfolds, sporadically with development of S'_1 metamorphic crenulation cleavage. S_1 planes have monoclinical position in mesodomain. E-W direction is a general direction of S_1 planes with dominating middle dip 30—50° with alternating direction of dip (to N and S), whereby the direction of dip to S is prevailing. Space position of S_1 planes (in mesodomain) make us to suppose the original macrofold (F_1) structural plan. B-axes of minor F_1 folds to microfolds, as well as constructed β-axes of F_1 macrofolds are of the E-W direction in paragneisses and mica-schist gneisses. Palimpsests of S_1 planes have also coincident direction as an inherited structural element in migmatites and unhomogeneous granites.

Fig. 6. A — A part of syncline of open macrofold (F_1 with B-axis E—W) of S_1 planes. Paragneiss. Locality: W of Hrabový vrch hill (southern block). B — Transversal compression of S_1 planes according to synmetamorphic lineation E—W, deformation of kink band type (F_2), with B-axis N—S. Paragneiss. Loc.: Železnica valley — Hontová (southern block). C — S_2 planes deformed by kink folds (F_2) with B-axis N—S. Phyllonites of overthrust zone of the southern block on the northern one. Loc.: E of Panská javorina. D — Core of recumbent concentric F_{1-2} macrofold with pointed similar mesofolds (with B-axis E—W). Diaphthorite of migmatitized gneiss. Loc.: Tri studienky (northern block). E — Slightly refolded limbs of isoclinal recumbent F_{1-2} macrofold with distinct lineation of minor folding (F_{1-2}) of E—W direction on the limbs, parallely with B-axis of F_{1-2} macrofold (originally F_1?). Loc.: Horný lom. F — Relictly preserved pointed hinges of recumbent isoclinal F_{1-2} mesofolds between S_{1-2} planes of axial plane of F_{1-2} folds. Diaphthorites of migmatites. Loc.: Ridge W of trigonometer Inovec (northern block). G — Disharmonic F_{1-2} folds. Diaphthorites of mica-schist gneisses with intercalations of metaquartzites. Loc.: Ridge NE of Jakubová (northern block). H — Non-competent diaphthoritized mica-schist gneisses folded in detail, with well developed S_{1-2} cleavage of axial plane of recumbent minor up to F_{1-2} microfolds. Loc.: Ridge NE of Jakubová (northern block). I — Diagonal F_2 mesofolds (with B-axis NE—SW) with S_3 planes of axial plane cleavage. Diaphthoritized eyed gneisses. Loc.: Mankovec valley (northern block). Photo: author.



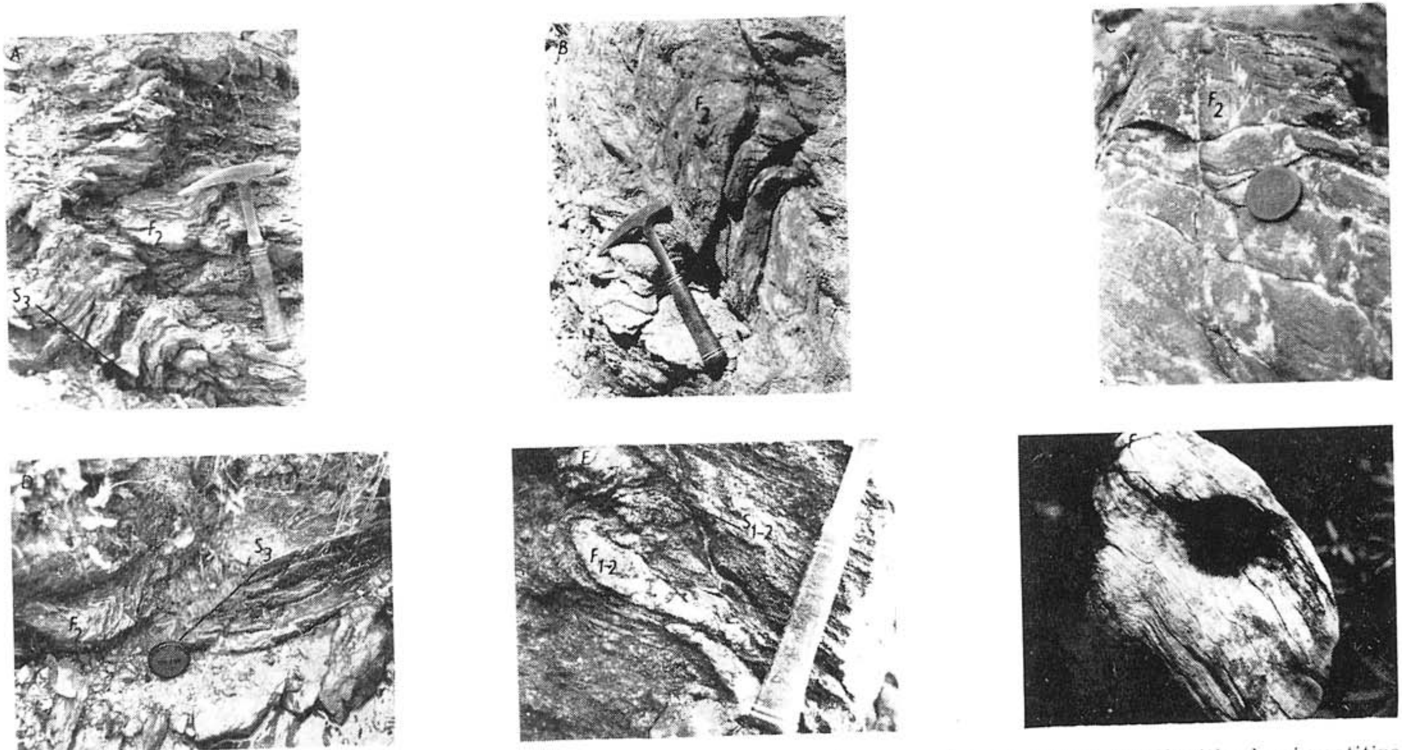


Fig. 7. A — Conjugate inclined up to overturned F_2 mesofolds with S_3 cleavage of axial plane. Phyllonitized migmatitized paragneisses. Loc.: Stoky (contact of the southern and northern block). B — Flexure (F_2) with B-axis NNE—SSW. Diaphthoritized gneiss. Loc.: Horný lom (northern block). C — Deformation of kink band type (F_2 with B-axis N—S) of S_1 planes. Paragneiss. Loc.: NW of Hrabový vrch hill (southern block), D — Pointed F_2 folds with B-axis N—S of steep plunging (50°), with S_3 planes of axial plane cleavage. Paragneiss. Loc.: Stoky (northern block). E — Hinges of isclinal F_2 mesofolds preserved relictly as lenticles of segregated quartz between S_3 planes. Migmatite diaphthorites? Loc.: Ridge W of trigonometer Inovec. F — Deformation of kink band type (with B-axis NNE—SSW) of metamorphic foliation. Middle Triassic limestone of envelope. Loc.: Hradisko (northern block). Photo: author.

D_{1-2} stage of deformation (analogous to D_{1-2} deformation stage of the northern block) has not been ascertained in exposed horizon of the southern crystalline block.

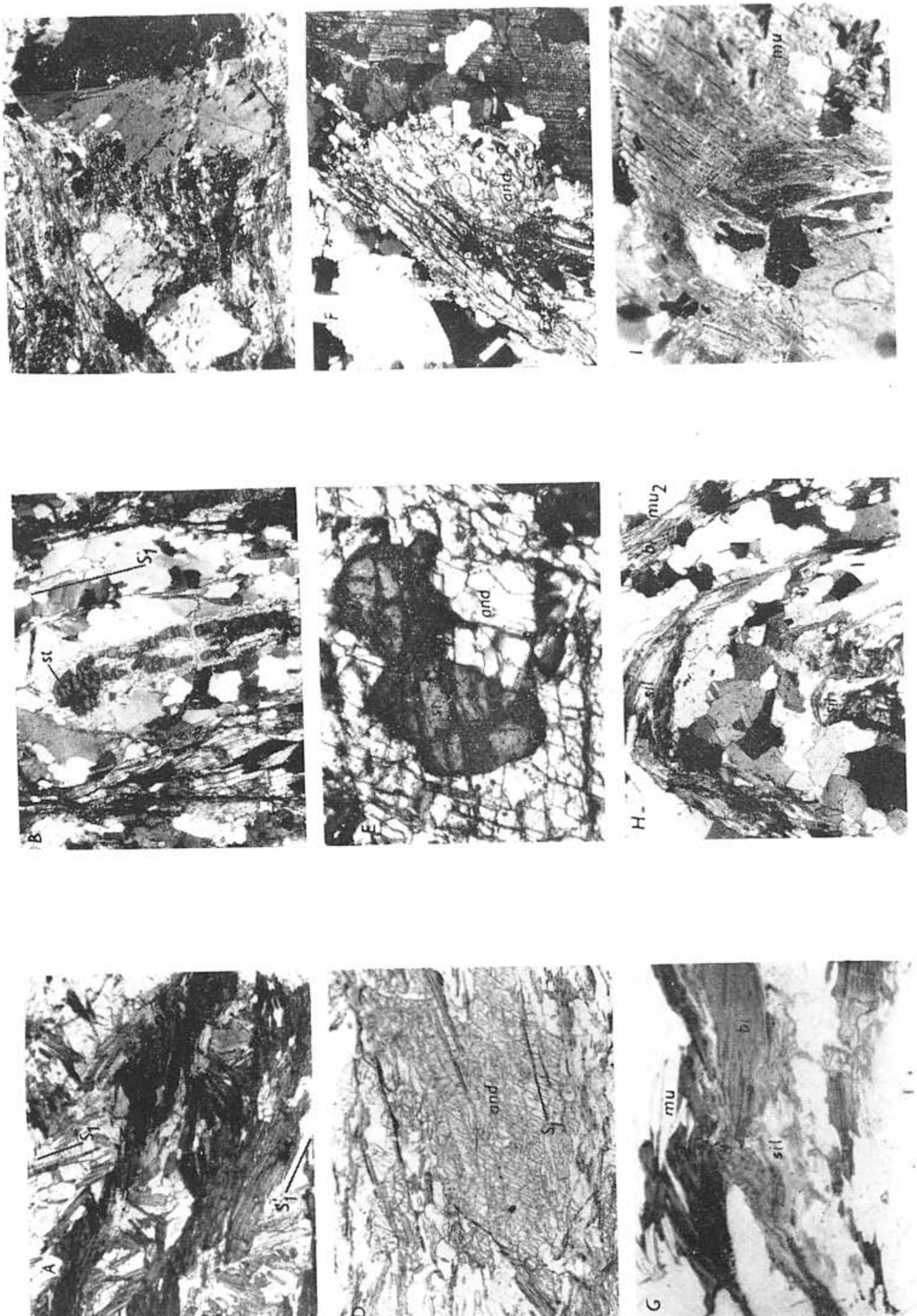
D_2 stage of deformation (S_2) is connected in the southern block with its overthrust on the northern block. S_2 planes are penetrative only in phyllonites of overthrust zone where they represent planes of phyllonitization of migmatites, paragneisses and mica-schist gneisses. Thickness of phyllonites varies from 50 to 100 m. S_2 planes have E-W direction with dip of 20—35° to the S. S_2 planes indicate the same position of overthrust plane (Hrádok — Zlatníky overthrust plane) of the southern crystalline block on the northern one.

D_3 sta ge of deformation (F_2, S_3) has a character of cross folding (according to direction of D_1 and D_2 structures), but also formation of general N-S mylonite

▶

Fig. 8. A — Synmetamorphic F_1 microfolds of S_1 planes with metamorphic S_1' cleavage. Paragneiss Loc.: W of Krislo (southern block), photo: H. Brodnianska. // (= parallel nicols), magn. x 15. B — Sericitized staurolite oriented on S_1 planes. Diaphthoritized mica-schist gneiss. Loc.: W of Panská javorina (northern block), photo: H. Brodnianska. X (= crossed nicols), x 15. C — Postkinematic albite encloses oriented, slightly folded and recrystallized (quartz, sericite, chlorite, albite) groundmass in Permian conglomerate. Loc.: Kočovská dolina valley (northern block). X x 10, photo: F. Martančík. D — Postkinematic porhyroblastic andalusite, sericitized at edge, encloses mostly chloritized biotite and quartz of S_1 planes. Slightly diaphthoritized migmatitized paragneiss. Loc.: Mráznica (northern block). // x 35, photo: F. Martančík. E — Andalusite encloses staurolite relic of S_1 planes. Slightly diaphthorized migmatitized paragneiss. Loc.: Mráznica (northern block). X x 150, photo: F. Martančík. F — Andalusite partly enclosed in mobilized basic oligoclase (with droplike quartz) of leucosome. Loc.: Mráznica (northern block). X x 20, photo: F. Martančík. G — Biotite sillimanitization. Migmatitized paragneiss. Loc.: Mankovec valley (northern block). // x 35, photo: F. Martančík. H — Biotite sillimanitization, most intensive in the hinge part of F_1 microfold; transversal muscovite$_2$. Quartzy paragneiss. Loc.: SW of Soľnisko (southern block). X x 13, photo: H. Brodnianska. I — Symplektic intergrowth of muscovite with sillimanite-fibrolite. Unhomogeneous (so-called hybrid) granodiorite. Loc.: SW of Soľnisko (southern block). X x 30, photo: H. Brodnianska.

Fig. 9. A — Tight F_{1-2} microfolds of micas of S_1 planes between S_{1-2} planes of newer cleavage system. Migmatite diaphthorite. Loc.: E of Ostrý vŕšok hill (northern block). // x 10, photo: H. Brodnianska. B — A part of biotite has a relict orientation of S_1 planes, a part is oriented according to a newer cleavage system of S_{1-2} planes. Mica-schist gneiss. Loc.: Hrádocká dolina valley (northern block). // x 25, photo: H. Brodnianska. C — Structure of polydeformed (F_{1-2} and F_2) diaphthoritized paragneiss. Loc.: NW of Panská javorina (northern block). // x 15, photo: F. Martančík. D — Flexure (F_2) of S_1 planes with B-axis N-S. Paragneiss. Loc.: W of Krislo (southern block). // x 10, photo: H. Brodnianska. E — Intensive biotite baueritization: deformation (F_2) of kink band type with B-axis NE-SW. Diaphthoritized migmatite. Loc.: Mankovec valley (northern block). // x 12, photo: H. Brodnianska. F — Biotite chloritization and baueritization; biotite is strongly deformed and cut across by S_3 planes of axial plane cleavage of F_2 microfolds with B-axis NNE-SSW. Diaphthoritized migmatite. Loc.: Mankovec valley (northern block). // x 33, photo: H. Brodnianska. G — Flexure deformations of feldspars and micas in aplitic-pegmatitic granite. Loc.: W of Trenćianske Jastrabie (northern block). X x 33, photo: H. Brodnianska. H — Strongly undulatory quartz in the hinge part of F_{1-2} microfold (with B-axis E-W) suggests development of S_{1-2} planes of cleavage fan. Mica schist. Loc.: Polámaný vrch hill (northern block). X x 10, photo: F. Martančík. I — Relict F_{1-2} microfold between S_{1-2} planes of newer cleavage system. Mica schist. Loc.: Prostredná dolina valley (northern block). X x 20, photo: F. Martančík.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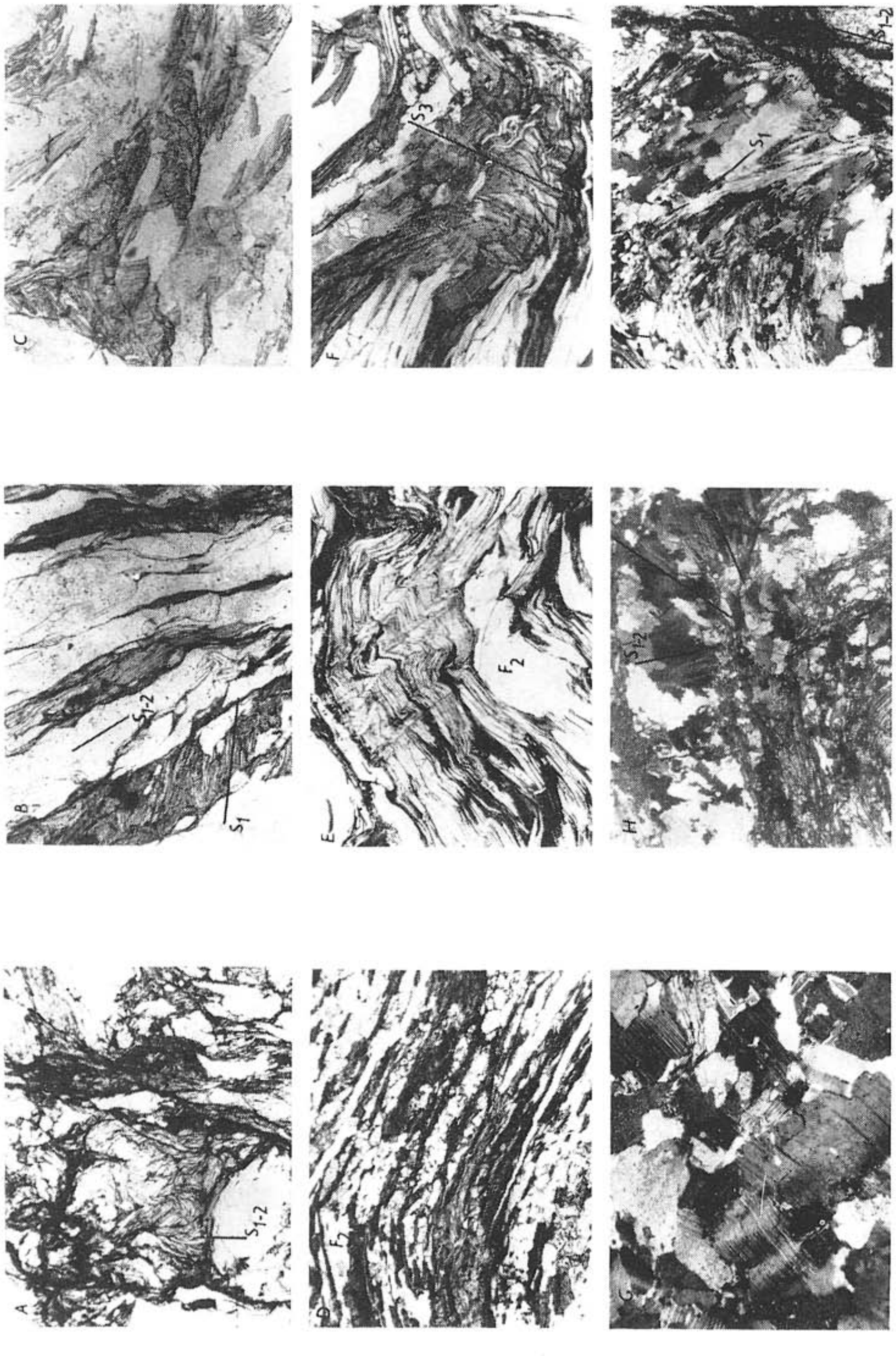
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zones is connected with it. F_2 folding is manifested by kink and conjugate mesofolds with plunging (10—55°) B-axis. F_2 folds were formed by cross refolding of the limbs of F_1 macrofolds. General direction of B-axes is N-S, whereby angle of dip and direction of dip depend on position of S_1 planes. S_3 planes represent planes of mylonitization in general N-S narrow, steeply inclined mylonite zones. F_2 folds deform the S_2 (D_2) planes of phyllonites of the overthrust zone (E-W). From it results that overthrust of the southern block on the northern one occurred before D_3 stage of deformation.

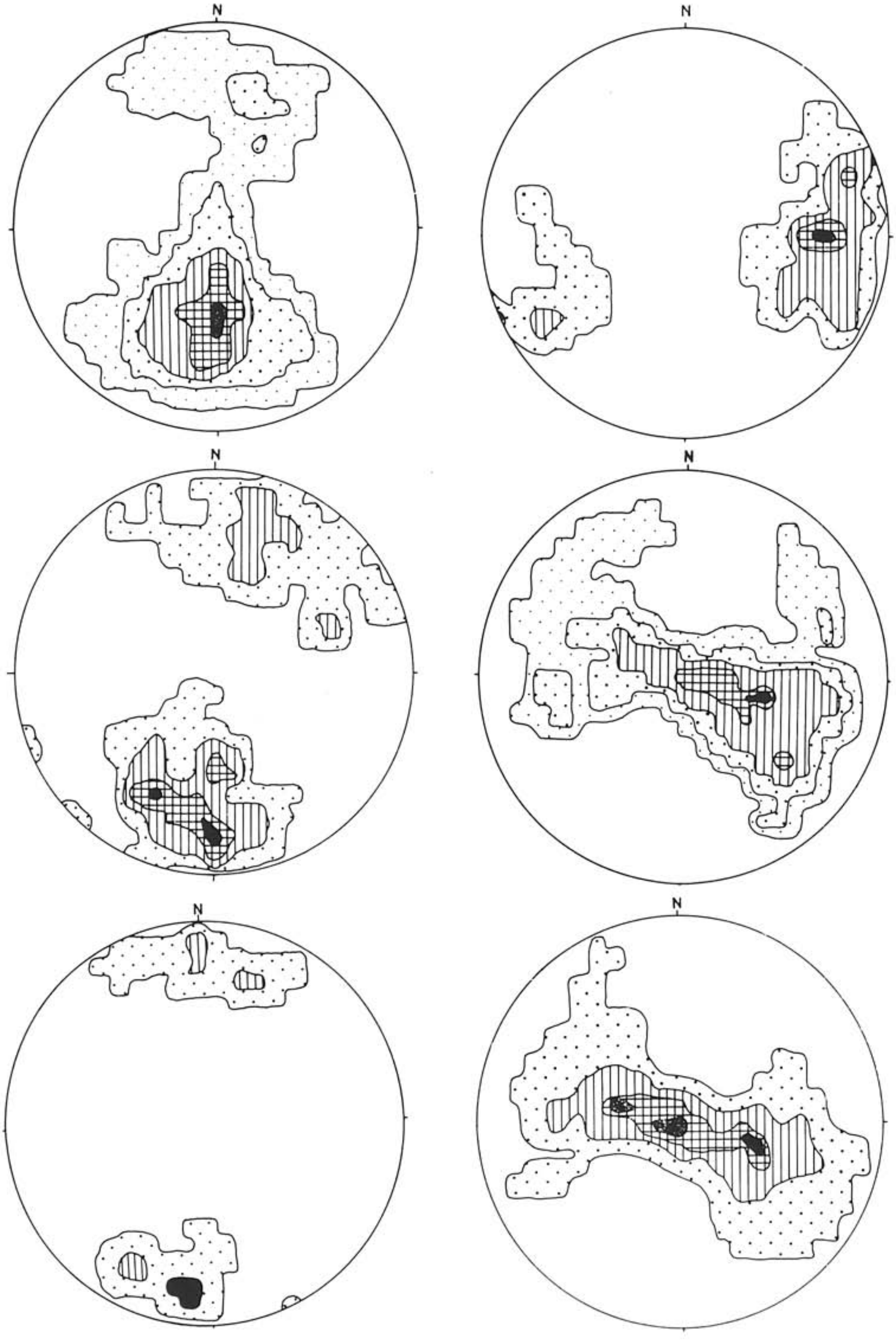
D_4 stage of deformation (F_3, S_4) is represented by the nonpenetrative F_3 macrofolds with steeply inclined (55—80°) limbs and B-axis of NNE-SSW direction. They occur, for example, in paragneisses on their contact with the envelope Lower Triassic quartzites E of Moravany, accompanying with S_4 axial plane cleavage.

D_5 stage of deformation is characterized only by direction deviations of structural elements of older stages of deformation from their general direction E-W (D_1, D_2) and N-S (D_3).

Discussion to age ranging of the crystalline complex, its metamorphism and deformations

By the means of palynological analysis of organic detritus (Čorná — L. Kamenický, 1976) data on Palaeozoic age (Silurian — Devonian, Devonian — Carboniferous, Carboniferous? Palaezoic) of original sediments of relatively slightly metamorphosed rocks — graphitic schists, graphic metaquartzites and lydites from Železnica valley (Duchoňka), i.e. from the southern crystalline block, have been acquired. From biotite of granodiorite from the southern crystalline block (locality Hradná skala) datum on age of 320 m.y. has been obtained by A/K^{40} method (Kantor, 1961). Neither palynological, nor geochronological analysis of the northern crystalline block is finished in the present and, for the time being, gives no data on age. Original sediments of the northern crystalline blocks were considered for Early Palaeozoic (J. Kamenický, 1956), later, on the basis of presence of pebbles of diaphthorites in Upper Carboniferous conglomerates for pre-Cambrian (J. Kamenický, 1958—1967).

Fig. 10. A — Contoured diagram of gradient straight lines of S_1 planes of the both crystalline blocks. 300 measurements. 10 — 6 — 4 — 2 — 0.5 %. (D_1 stage of deformation). B — Contoured diagram of B-axes of F_{1-2} folds of the northern crystalline block. 80 measurements. 10.5 — 6.5 — 3 — 0.5 %. (D_{1-2} stage of deformation). C — Contoured diagram of B-axes of F_2 folds of the both crystalline blocks. 120 measurements. 10 — 6 — 3 — 0.5 %. (D_3 stage of deformation). D — Contoured diagram of gradient straight lines of S_3 planes of the both crystalline blocks. 200 measurements. 10 — 7.5 — 3.5 — 1.5 — 0.5 %. (D_3 stage of deformation). E — Contoured diagram of B-axes of envelope Palaeozoic and a part of envelope Mesozoic folded into the crystalline basement. 60 measurements. 9 — 6 — 0.5 %. (It corresponds to D_3 deformation stage of the crystalline basement, to F_2 folds). F — Contoured diagram of gradient straight lines of envelope Palaeozoic foliation and a part of envelope Mesozoic. 320 measurements. 7.5 — 5.5 — 2 — 0.5 %. (It corresponds to D_3 deformation stage of the crystalline basement).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In the substantial part of the crystalline basement of the both blocks of the Považský Inovec Mts. any principal differences in lithological, metamorphic and structural development have not been ascertained. But relatively slight metamorphic formation of the southern crystalline block, out of which the palynological data on Palaeozoic and especially Lower Palaeozoic age have been acquired, is beyond this framework. Unfortunately, only fragments of these rocks are presented. These members accompanied with amphibolites are preserved in a higher amount in the western part of the Suchý massif in the Strážovské vrchy Mts. (analogous crystalline basement as the southern block of the Považský Inovec Mts.), from which age data on Lower Palaeozoic were gained by palynological analysis (cf. Čorná — L. Kamenický, l.c.).

There are most probably two groups present in the crystalline basement of the Považský Inovec Mts., out of them the upper one is of Early Palaeozoic age and the lower one (polymetamorphic, polydeformed) is possibly from pre-Cambrian (?).

Pre-alpine deformation in this mountain range has been briefly marked as D_1 deformation stage. Pre-Hercynian (?) tectonic style of open macrofolds in paragneisses of overthrust block has been partly modified by the processes of partial anatexis and penetrating of Hercynian granitoids to metamorphic envelope.

Age of older metamorphic event (staurolite isograd) and of S_1 planes within the framework of pre-alpine (pre-granitoid) regional metamorphism appears as pre-Variscan (Assyntic?, Caledonian?). Newer metamorphic event under the conditions of andalusite and sillimanite isograd, also anatectic migmatitization and formation of granites of palingenetic-anatectic origin (in deeper horizons of the crystalline complex) are due to Variscan orogeny.

D_{1-2} stage of deformation (temporally between D_1 and D_2) is considered to be pre-alpine (pre-Upper Carboniferous) connected with retromorphism.

D_2 and D_3 stages of deformation are connected with palaeoalpine folding and low-degree alpine metamorphism and dynamometamorphism of Palaeozoic-Mesozoic envelope, as well as alpine retromorphism of the crystalline basement are bound to it.

D_4 stage of deformation is supposed to be in connection with Laramide (?) phase of mesoalpine folding.

D_5 stage of deformation is connected with formation of arc course of outer edge of the central West Carpathians during neoalpine folding.

Kálnica fault (Putiš, 1980) of general WNW—ESE direction between Kálnica and Zlatníky belongs to fault structures of steeper dip with later manifestations than D_4 stage of deformation. According to the fault an uplift (x 100 m) of the southern segment occurred. Normal up to reverse Selec fault between Selec and Dubodiel belongs to this system too. Minor lateral movement (x 10 — x 100 m) occurred on these faults. Boundary faults of megahorst of the Považský Inovec Mts. belong to young — post-Palaeogene faults.

Translated by O. Mišániová

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Review by Š. KAHAN, L. KAMENICKÝ Manuscript received July 22, 1982