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THE POLYCYCLIC CHARACTER OF THE SOMEŞ SERIES METAMORPHICS IN THE WEST CARPATHIANS (ROMANIA)[1]

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The polymetamorphism of the intensely metamorphosed crystalline units in the Carpathians appears as a natural phenomenon in light of stratigraphic-protistologic and geochronological data. Nevertheless, petrological and microtectonic arguments have not yet been given proper attention.

The present paper proposes to account for the polycyclicity of the Someş Series metamorphism on the basis of (1) the microtextural relationships in which phaneroblastic mineral components are implied; (2) the chemical changes during the blastesis of some of these components; (3) the analysis of microtectonic elements, a.s.o. The rocks examined are mainly metapelites, which abound in the area.

The Someş Series is the most intensely metamorphosed section of the Gilău Crystalline. To the west and to the east it borders on the granite block of the Muntele Mare. Its lithology is relatively homogeneous, consisting mainly of quartz-micaceous schists, micaschists and quartzites, as well as quartz-feldspar gneisses. Amphibolites, graphitic quartzites, crystalline limestone and spessartite rocks can be also found, but they have a subsidiary importance. The lithostratigraphic succession that has been set up starts with a metapelitic complex and by a migmatised metapelitic complex at the top.

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The Someș Series has been estimated to date from the Upper Precambrian, and the Muntele Mare granites from the Paleozoic.

The formations belonging to the Someș Series have been studied by several authors, the best known among them being Dimitrescu (1958, 1966), Giușcă et al. (1968), Mârza (1969), Mureșan (1980). In the framework of their papers they mention the bimetamorphic nature of these formations, implying especially the retrogressive chloritization overlapping an older regional metamorphism. At the point of contact with the Muntele Mare granite they unanimously acknowledge a thermic metamorphism.

Textural Relationships

In the present paper the study of the metamorphic processes will be made by taking into consideration the stages of deformation materialized in S planes and linear elements correlated with stages of mineral neoformations, or with relict minerals, and in connection with parageneses or more recent deformations.

The oldest mineral association includes kyanite, staurolite and garnet, which are also found as minerals of neoformations, albeit they have different characteristics. The first generations of kyanite and staurolite (d_1 and st_1) are represented by very minute crystals. They are randomly oriented with respect to any of the S planes noticeable at present, being chaotically piled up within some highly flat lenses. The xenomorphic nature and the deformed aspect of the kyanite and staurolite crystals are characteristic features, as well as the chemical distinctions between the central and marginal zone of individual crystals (at least in so far as the content of inclusions is concerned) (Fig. 1).

Fig. 1. — Polycrystals lens of kyanite, staurolite, garnet ± sillimanite in S_2 plane. sill—sillimanite; ky — kyanite; st — staurolite; bi — biotite; gar — garnet.

The first generation garnet is very clear or has very fine inclusions in the central zone, displaying a marked idiomorphism and suggesting a very slow growth toward the end of its formation. It has preserved its idiomorphism, by supergrowth, owing to the superposition of a synkinematic garnet different chemically, during a later stage, marked by an increased rate of growth (Fig. 2).

The deformation stage D_2, which individualizes the first generation of staurolite, kyanite and garnet with respect to time, materializes in an S plane with a highly penetrating character. At its level, massive neoformation of micaceous minerals and lens-like segregations occur. These lenses vary as to thickness (millimeters-decimeters) and their lengths are noticeable at outcrop, where they measure several meters (Fig. 3).

Quartz segregation can be correlated in time with the beginning of the crystallization of the second generation garnet. This can be determined on the basis of the great number of quartz inclusions with which its formation starts. In the same S plane, as a result of the D_2 deformation stage (S_2 plane), polymineral lenses measuring millimeters are also formed, which consist of kyanite and/or staurolite, quite often associated with

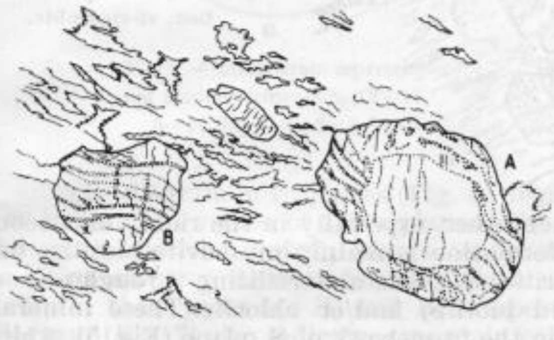

Fig. 2. — Optically zoned garnet (A) and younger unzoned garnet (B), from Someş Series.

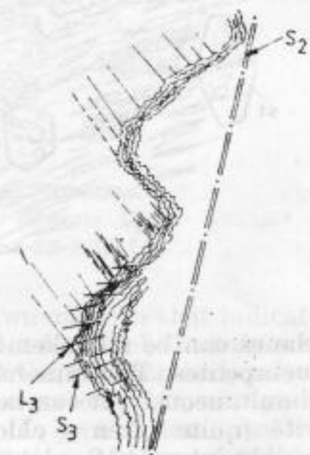

Fig. 3. — Superposed structures B_2 and B_3 in the Someş Series.

garnet. The S_2 plane also materializes by layering in quartz-fedspathic or amphibolite rocks, or by alternations of micaceous layers with quartzite or quartz-feldspathic ones in metapelitic rocks.

The pronounced penetrating nature of the S_2 deformation plane has had an especially strong deformation effect, giving rise to (1) notable discontinuities of initial stratification planes ($S_{0,1}$), (2) discontinuities of some rock blocks with restricted dimensions (amphibolites, quartzites) and (3) the crushing up of minerals with lengthened prismatic habit (the kyanite and staurolite in the above mentioned lenses). The penetrating nature of S_2 plane has also left its trace in a transposition effect at the level of this plane and the apparent orientation of all the rock blocks, at mesoscopic level, after S_2.

The mineral neoformation related to stage D_2 is predominantly micaceous, but also garnet and quartz-like, as noticed above. It is likely that the D_2 metamorphic stage has a postkinematic static component too, represented by the supergrowth of kyanite and staurolite from the lenses containing these minerals and, possibly, by individual crystals of kyanite and staurolite (Fig. 4).

A next deformation stage, D_3, materializes through a S_3 crenulation plane present everywhere in the area, characterized by a penetrating nature of variable intensity. In the zones where this characteristic is especially well represented, the crenulation schistosity is also very visible macroscopically, obliterating the foliation S_2. This is the reason why S_2 and S_3

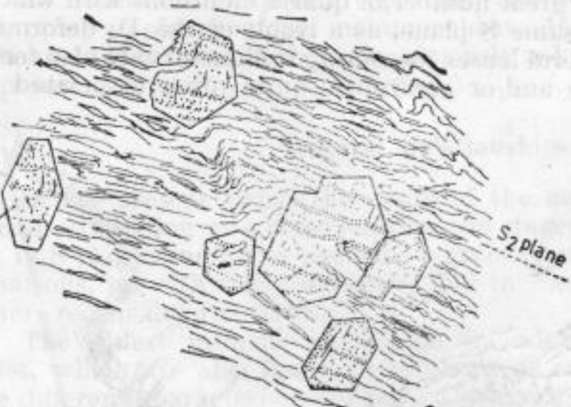

Fig. 4. — Staurolite postkinematic porphyroblasts grown post D_2-deformation. st-staurolite.

planes can be mistaken for each other, especially in the richly micaceous metapelites. The mineral neoformation is mainly muscovite-biotitic, but simultaneously, it can be chloritic, S_3 plane materializing through muscovite (quite often $\pm$ chloritized biotite) and/or chlorite. These minerals visibly intersect S_2 plane within the framework of S_3 plane (Fig. 5) which

Fig. 5. — Crenulation S_3 plane, cutting S_2 plane. cl — chlorite; gar — garnet.

points to their subsequent character. A mineral neoformation stage related to D_3 stage, but having a postkinematic, static nature is represented by the random orientation of biotite and especially of chlorite in the rock texture.

Microtectonic Considerations

The measurements of mesoscopic planar and linear elements concerning exclusively S_2, S_3, L_2 and L_3. $S_{0,1}$, even when the measurements are taken at the point of contact between the contrasting lithological elements, represent the transposition effect of $S_{0,1}$ plane by S_2 only. The possibility of confusing S_2 and S_3 planes has led us to consider only those outcrops in which both planes were noticeable.

The statistical processing of the measurements of planar and linear elements was carried out through stereographic projection on Smith's network with equal surfaces, in the lower hemisphere.

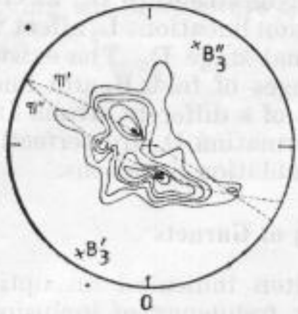

Fig. 6. — Stereogram representing planar elements S_3.12—10, 5—7. 5—4. 5—3—1,5%

Fig. 7. — Stereogram of linear elements L_3. 14-10,5-8-5,5-4-2,5-1 %

The diagram of S_3 planes (Fig. 6) displays two maxima that indicate low inclination values of these planes. The manner in which the values of the spatial positions of S_3 planes center around the two maxima, seems to point out two distinct foliation populations represented in circles π' and π''; their poles are B_3' and B_3'', respectively. L_3 crenulation lineation diagram (Fig. 7) also indicates two main concentrations of these elements, likewise situated at very low inclination values. The positions of the two maxima (B_3^a and B_3^b) agree with the foliation poles of the π circles mentioned above (B_3', B_3'').

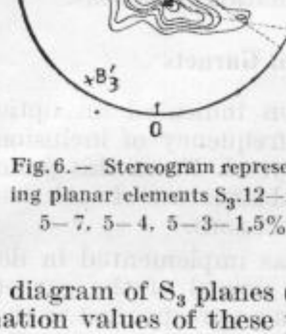

Fig. 8. — Stereogram representing planar elements S_2 10-6-4-2%

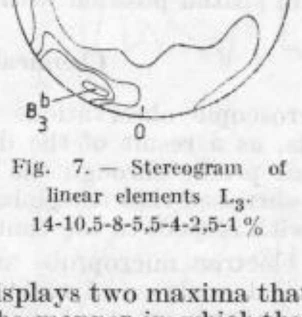

Fig. 9. — Stereogram of linear elements L_2. 15-11-6,5-4-2%

The diagram of S_2 planar elements (Fig.8) is characterized by high inclination values and constant direction of these planes. The linear elements L_2 (Fig. 9) concentrate primarily in the pole B_2' and to a lesser extent in B_2'', which coincide with B_3 poles. This coincidence is forseeable because the crenulation lineation is in fact an intersection lineation of crenulation plane S_3 with S_2 plane.

The analysis above reveals a sensible individuality of D_2 and D_3 deformational elements, manifest by the different position of poles of S_2 and S_3 planes. The subsequent character of structure B_3, as compared to B_2 also results from the fact that crenulation lineations L_3 affect the characteristic concentrical folds of deformational stage D_2. The existence of an angle, generally sharp, between the hinges of folds B_2 and lineations L_3, proves that they have formed as a result of a different strain. In contrast, the similar folds developed owing to deformation D_3 are perfectly identical in terms of spatial position with the crenulation lineations.

Chemical Zoning of Garnets

Microscopic observations have often indicated an optical zoning of garnets, as a result of the dissimilar frequency of inclusions along a transversal profile through the garnet crystal. From this point of view, it can be surmised that the global chemical structure of each zone changes at least with respect to the content of inclusions.

An electron microprobe analyser was implemented in determining the chemical analyses of regions within several of the garnets. It was determined that a cryptical chemical zoning corresponded to the observed optical zoning in these porphyroblasts. It was also shown that the chemical zoning is less pronounced when the metamorphism of garnet-bearing rocks is more intense, which is due to the homogenization of initially zoned garnets at the high temperature conditions.

We shall present below the analysis of a zoned garnet in the Someş Series. It consists of a clear central part with an idiomorphic contour. We consider it to belong to an initial stage of metamorphism. The beginning of the second zone is marked by quartz and indeterminate inclusions that border on the preceding zone. They are orderly disposed, S_1 displaying a sigmoidal shape. This arrangement testifies to the synkinematic character of the second zone.

The chemical analyses have been made with the help of an ETEC electronic microanalyser. All standards and standard chemical analyses are from the Mineral Constitution Laboratory at the Pennsylvania State University. The profile along which the analyses have been made is indicated in the adjacent figure (Fig. 10). Its length was 1.620 mm, and the step scan was 0.075 mm. The elements analysed and represented in the diagram as oxides are Fe, Ca, Mg, Mn and Ti.

All analyses are presented in terms of oxide mole percent with the FeO profile relying on a different ordinate scale. The PSU microprobe analyses with an approximate 3–4 micron diameter excitation area. Analytical uncertainties, were determined by X-ray counting statistics. Fluctuations in zoning profiles are probable artifacts of uncertainties, the interception of inclusion and/or possibly real. Nevertheless, general trends in chemical zoning can be determined. The large Ti content at 1.425 mm of the garnet in Figure 10 was produced by an ilmenite inclusion which was analysed with the garnet. The diagram of chemical content along the transversal profile reveals an obvious correspondence between the optical zoning and the one resulting from chemical fluctuations. The outer 0.3 mm of the garnet possesses abruptly reversed chemical profiles in the major cations, CaO displaying the most severe zoning. Manganese has a bell-shaped profile

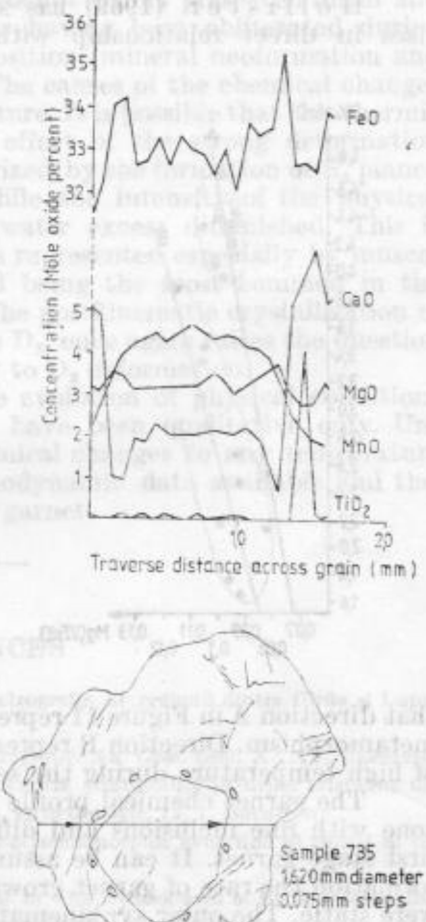

Fig. 10. — Compositional profiles in an optically zoned garnet

with simple symmetry as a result of a continuous drop in MnO during the garnet growth. But FeO, CaO and even MgO display complex symmetrical profiles, as a result of the discontinuous nature of the growth, which is commonly ascribed to polyphasic metamorphism (E d m u n d s and A t h e r t o n, 1971).

Along the transversal chemical profile one can notice a diminution in the Mn content in the same direction as the Fe increase, which produces a rise in the almandinic component to the detriment of the spessartinic one. This might indicate a general level of the rise in the physical conditions of metamorphism.

The diminution in the CaO content, or, in other words, the decline of the grossularite component, implies a temperature rise and a slight increase of pressure or a stationary level of the latter, a point on which we agree with Raheim and Green (1974).

Hollister (1969) has shown that the garnet MgO/FeO ratio rises in direct relationship with the metamorphic degree, suggesting

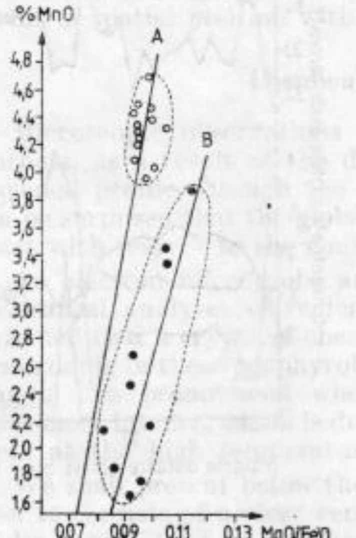

Fig. 11. — Plot of MnO versus MgO/FeO for zoned garnet (sample 735).

○ Values from core of garnet

● Values from edge of garnet

that direction A in Figure 11 represents high P and T conditions of regional metamorphism. Direction B represents the garnet growth under conditions of high temperature during the second stage of growth.

The garnet chemical profile is not complete, as it does not have the zone with fine inclusions and diffuse margins in the central part of the first stage garnet. It can be assumed that during the first period of its formation the rate of garnet growth was higher, but its growth conditions were static. The outer synkinematic growth zone, accompanied by a temperature rise, can be correlated with deformation D_2 and implicitly with the formation of foliation S_2. The rise of temperature in this period could be correlated with the thermic effect of Muntele Mare granite, which has a gneissic character in the marginal zone. The mineral neoformation in this stage was thus the result of the position with respect to the thermic source, with andalusite blastesis in the close vicinity of the granite, with sillimanite nucleation on the old kyanite and with the static rise of kyanite and staurolite in the more distant zones from the granite. It follows that the synkinematic sequence represents only a part of the thermic period generated by the granite or another source quasisynchronous with it.

Conclusions

The corroboration of the deformational elements with the textural relationships and with the chemical changes during the growth of the garnet have furnished us with arguments for distinguishing three important stages in the development of the Someş Series metamorphism. The first and oldest stage is characterized by the association of kyanite with staurolite and the first generation garnet. It has not visibly preserved linear and planar synchronous elements, these ones having been obliterated during stage D_2 in virtue of a marked transposition (mineral neoformation and reorientation) at the level of S_2 plane. The causes of the chemical changes in the garnet seem to be thermic as to nature. It is possible that this thermic surplus should represent an energetic effect of the strong deformation during stage D_2. Stage D_3 was characterized by the formation of S_3 planes with variably penetrating character, while the intensity of the physical factors of metamorphism and of the water excess diminished. This is the reason why mineral neoformation is represented especially by muscovite, biotite, chlorite — the last-named being the most common in the eastern part of the investigated area. The postkinematic crystallization of biotite and chlorite with respect to stage D_3, once again raises the question of a surplus energetic effect with respect to D_3 deformation.

The considerations concerning the evolution of physical conditions during these stages of metamorphism have been qualitative only. Unfortunately, we cannot ascribe the chemical changes to any temperature change, owing to the lack of the thermodynamic data available and the complex multicomponent zoning of the garnet.

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