STRAIN ANALYSIS IN THE PERMIAN OF THE CORNEREVA-MEHADIA ZONE (SOUTH CARPATHIANS, ROMANIA)

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The deformation analysis at different scales of Permian conglomeratic rocks in the Mehadia-Cornereva region evidenced their microstructural evolution as a first step in the initiation of a shear zone. From N to S a continuous from homogeneous deformation to a heterogeneous one can be observed, concomitantly with an increase of intracrystalline plasticity until reaching the stage of partial recrystallization of quartz. The variation of final axial dimensions as well as of other parameters shows the superposition of deformation on the plane strain domain, the calculated values increasing in the same sense, together with the extension of foliation.

Key words: strain analysis, Permian, Banat-South Carpathians, plane strain.

1. GEOLOGIC FRAMEWORK

Our recent investigations on the Permian formations of the Cornereva-Mehadia (Presacina) zone, South Carpathians (Banat), allowed us a series of observations conducing to an improved image of the regional structure.

With the exception of the lower course of the Hideg, the Permian formations build up a NS oriented continuous strip between the Globu and Secăreştița valleys, its length being of 15 km and its width,1 to 3 km.

Our observations were carried out on the well exposed valleys of Jardăştița, Sfârdinu, Globu and Hideg (Râul Rece=Cold River) (Fig.1). According to Năstăseanu (1979) and Stan *et al.* (1986), the basement of the Permian formations situated on their western side, is represented by so-called "Corbu Series" of the Danubian (retrogressed micaschists, chlorite-calcschists, crystalline limestones, graphite-schists).The hanging wall, on their eastern side, is represented by Lias; both the eastern and the western contacts of the Permian, are masked by NS oriented faults. Along the western course of the Hideg valley, in the Râul Rece Nappe, the same Liassic cover appears, while eastwards the basement is represented by the Sevastru argillites (Visean) (Stan, 1985; Năstăseanu, 1979; Năstăseanu *et al*., 1988).

The lower horizon of the Permian (ca 300 m) shows a predominantly conglomeratic character (with pebbles of quartz bearing ± keratophyres) while the upper one (ca 500 m) is formed by red sandstones, argillites and tuffites. Vulcanites, are intercalated only east of Mehadia (*e.g*. Străjiuța hill) (Stan *et al*., 1986).

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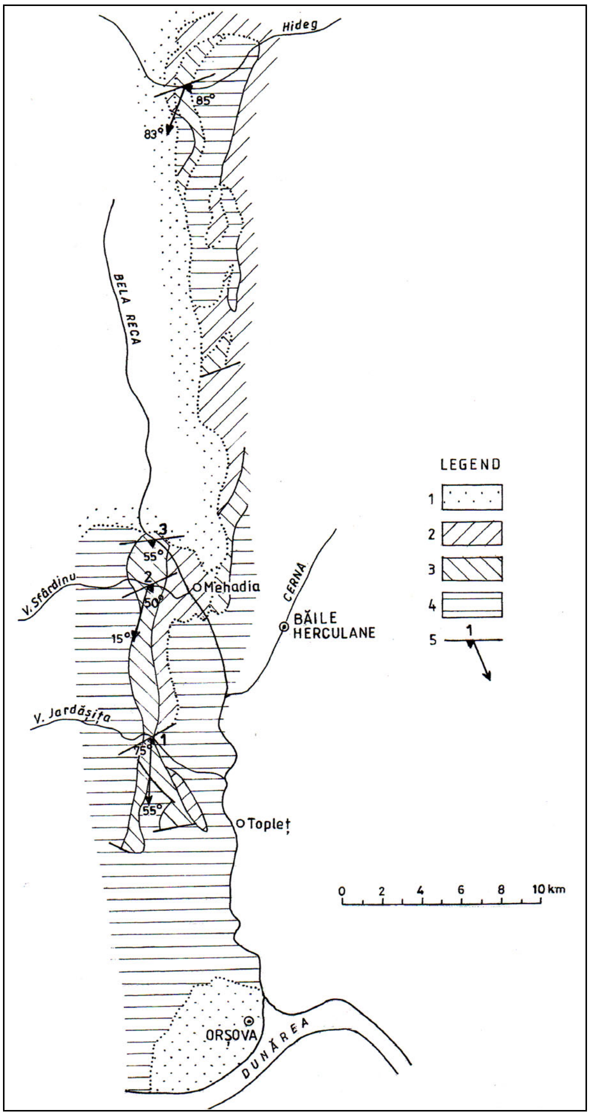

Fig. 1 – Geologic sketch of Permian formations in the Cornereva-Mehadia zone. 1-Tertiary; 2-Mesozoic; 3-Permian; 4-Crystalline + Lower+ Middle Paleozoic; 5-Point of observation, foliation and lineation.

Stan (1985) was the first author to underline a weak metamorphism of the Permian formations, without entering into details.

Our observations concerning the microtectonics of Permian formations showed that the same mesoscopic structures are present as in the Permian of the Apuseni Mts. (Dimitrescu *et al*., 1965; Bleahu *et al*., 1982),studied in detail by us (M. Dimitrescu, 1995, 1998, 2000).The main feature is the frequent superposition of a penetrative schistosity (cleavage) S_1,constantly superposed on the primary stratification S_0. All along the exposed Permian from the Jardăştiţa valley in the South to the Hideg valley in the North, this schistosity strikes constantly ENE-WSW, with a SSE dip. The initial stratification S_0 has different attitudes, an anticline being observable along the Sfârdinu valley (S_0 being measured directly or constructed). The $L_1 = S_1/S_0$ intersection lineation is oriented predominantly NNW to NS, the axial dip of the structure being southwards (L_1 = NS/S) along the Jardăştiţa valley only.

The microtectonic investigations of the deformed pebbles in the conglomerates, was carried out on the same principles as in the Apuseni Mts. (M.Dimitrescu, 1995, 1998). In Bihor, the age of this tectonics had initially been considered as Late Variscan (R.Dimitrescu *et al.*, 1965) but subsequently we concluded that it may be Alpine (R.Dimitrescu, 1988; M.Dimitrescu, 1995, 1997).The same conclusions may be formulated from our present investigations.

2. MICROSTRUCTURE

The microscopic analysis was realized on slides cut parallel with the XZ surface of exposures, the description following especially the evolution of microstructures in the matrix of the conglomerates. We stressed upon the granular agglomerates and the isolated quartz crystals which, being "strain sensitive", furnish valuable information on the kinematics at microscopic scale, correlatable with certain mesoscopic observations.

In the Globu quarry, the rocks lack oriented texture (Fig. 2). Many quartz grains show boundaries with straight morphology, but also ondulose extinction and deformation lamellae, which are the first to develop in the conditions of low metamorphism.

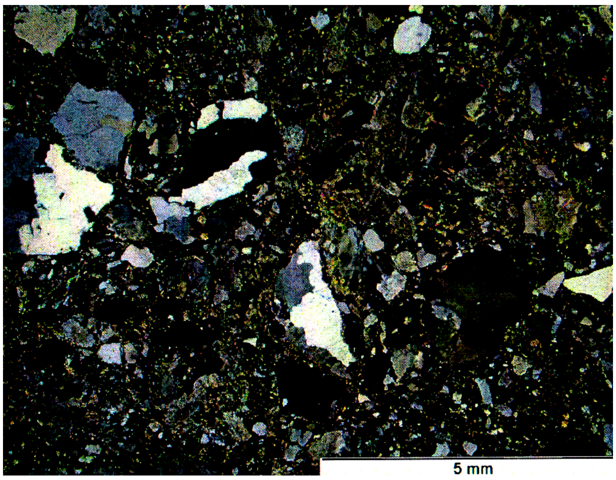

Fig. 2 – Matrix with unoriented structure. Quartz clasts with ondulose extinction and straight intercrystalline sutures. Globu quarry, sample 609, N +.

On the Sfârdinu valley, new microstructural aspects appear such as: increase of the number of quartz grains with ondulose extinction and of the frequency of sub-grains; the foliation begins to be marked by the alignment of sericite and its crystallization in pressure-shadows associated with opaque minerals or fragments of pyroclastites. The feldspar crystals are common, having angular boundaries and frequently appearing chemically altered, slightly deformed or showing microfractures (Fig. 3), all features being clear effects of tectonic strain.

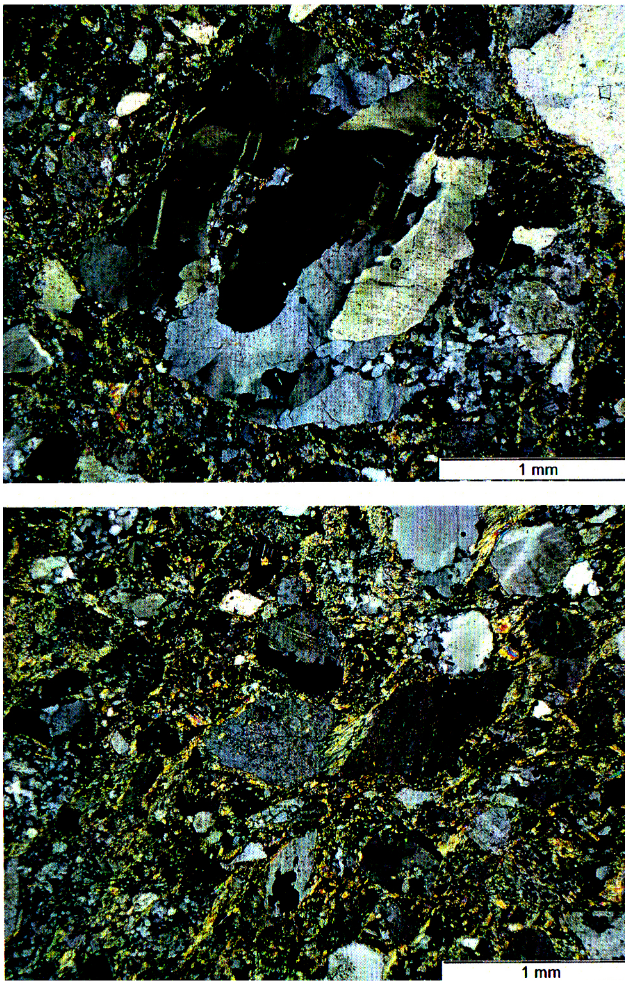

Fig. 3 – Quartz crystals agglomerations with large developed ondulose extinction. Apparition of sub-grains and of peripheric recrystallizations. Sfârdinu valley, sample 662, N +.

The progressive deformation of the rocks along the Cornereva-Mehadia alignment is based upon microscopic observations on kinematic indicators recognized in its southern extremity, at the confluence of the Jardăştiţa Mare and

Jardăştiţa Mică valleys. The increase in number of clasts with elongate shape is remarkable, producing an “elongate grain fabric”. Numerous quartz grains and polycrystalline aggregates contain irregular sub-grains, the boundaries of which are indented due to the migration of margins. We mention the apparition within old deformed grains of new recrystallized ones (Fig. 4). Other observations concern the morphology of boundaries of quartz porphyroclasts, which, being irregular, show incipient dynamic recrystallization but also coexistence of deformed quartz grains with undeformed ones.

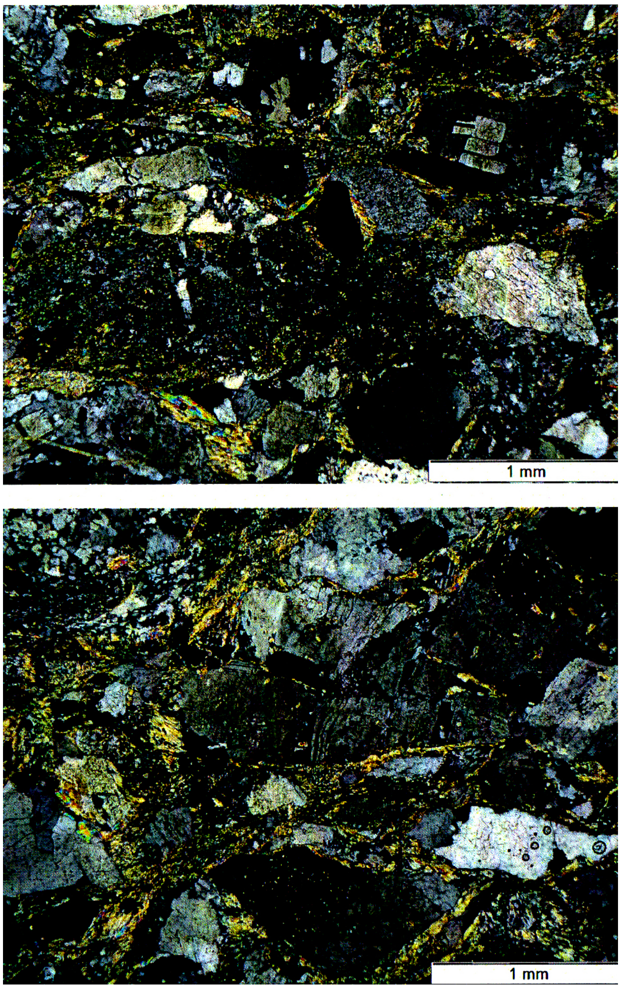

Fig. 4.Oriented structure in metaconglomerates of Jardăştiţa Mare valley. Feldspar clasts with curved twins and microboudins. The concentration of recrystallizations and sub-grains in the marginal zones of quartz crystals. Sample 192, N +.

Numerous mono-mineral clasts and matrix fragments show incipient symmetric tails. The strain-shadows contain generally fine sericite crystals with a more pronounced orientation than the surrounding mass, a characteristic aspect of progressive deformation (Ramsay, Huber, 1983). The sericite fibers are straight and the long axes of these microstructures probably imitate the orientation along the X direction of finite strain. The rectitude of fibers shows on the one hand the short history of deformation and on the other hand, constant parameters of flow (Passchier, Trouw, 2006).

The consistent development of the described structures, their symmetry as well as the micro-boudinage, are elements which define a plane strain by pure shear.

Another aspect has to be underlined: the coexistence of deformations in ductile regime and in brittle one. This aspect is visible almost exclusively in feldspars, by the presence of micro-fractures, of broken and boudinaged clasts, as well as by curvatures of twinning planes and ondulose extinctions (Fig. 4).

3. STRAIN ANALYSIS

In order to realize the strain analysis, ca 150 pebbles were measured tridimensionally, following the classical techniques. Having in mind the competence contrast between clasts and matrix, the obtained results represent the minimal strain estimated for the whole rock. According to the values of final axial ratios (R_f) needed for the classification after shape, the mean ellipsoids characteristic to every observation point are of triaxial type for the Sfârdinu and Jardăştiţa valleys, respectively of slightly oblate type in the case of the Globu quarry (Table 1).

Table 1

Strain values of pebbles

Nr.	Location							R_s			
		X/Y	Y/Z	X/Z	Z/Y	k	XY	YZ	XZ	R_i	E_s
1.	Jardăştiţa v.	1.99	1.47	2.94	0.67	1.19	1.93	1.41	2.67	1.05	0.80
2.	Sfârdinu v.	1.71	1.37	2.35	0.72	1.24	1.54	1.32	2.00	1.10	0.62
3.	Globu quarry	1.18	2.00	2.38	0.49	0.59	1.12	1.47	2.03	1.20	0.67

The k parameter ($k = X/Y / Y/Z$) which controls the distribution of points on the Flinn diagram (Fig. 5) is situated within the limits of plane strain $0.7 < k < 1.3$. Their position on both sides of the line $k = 1$ in the vicinity of the coordinate axes origin, shows a slight progressive deformation by flattening (3) and extension (1, 2). The mathematical results are sustained by field observations which show that in the Globu quarry the rocks were only flattened, the clasts conserving the initial random distributions. In this case, the value $X/Y = 1.18$ reflects their original shape before the flattening; on the other hand in the points of observation 1 and 2, the more intense deformation led to the orientation of the long axes of pebbles parallel to the direction of shearing. A comparison of ellipticities along the surfaces equivalent to the principal planes of the strain ellipsoid shows their deformation on XZ, where $R_f > 2$, versus XY and YZ which expose contours with R_f between 1.18 and 1.99, respectively 1.37-2.00. The extremely low variation of R_f YZ from 1.32 to 1.47 underlines the plane character of the deformation. The calculated values for XZ and YZ cover restrained domains, very near 0.59 respectively 0.63 (Table 1).The 4% difference between them constitutes an argument to consider that in the studied area, the metamorphic conglomerates conserved the primary aspect on the XY surfaces (Hutton, 1979).

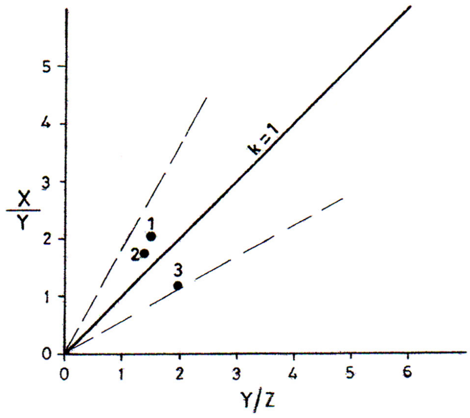

Fig. 5 – Flinn diagram.

Concerning the mean initial dimensions of pebbles (R_i) the data included in Table 1 show ellipsoidal-quasi-spheric shapes, with R_i between 1.05 and 1.20. Concerning the Globu quarry, it is evident that along the schistosity surfaces, the clasts conserved their shapes unchanged, the mean of R_i being approximately equal to the R_f, this fact underlining the importance of XZ surfaces of the exposure for the registration of deformations.

The strain ratios (R_s) show unimportant variations on all the planes, with values slightly highes on XZ (Table 1). Generally, values $R_s > 1.80$ are considered to be as expressions of tectonic strain (Bankwitz, Bankwitz, 1989).

In order to facilitate the comparison between the observation points, we calculated the E_s parameter, as a measure of strain intensity, using as a base value an initial spheric shape of the clasts (Hossack, 1968).The results shown in Table 1 demonstrate that the studied rocks underwent a strain of low magnitude, $0.5 < E_s < 1.0$. As in the case of k parameter a slightly increasing non-uniform tendency from N to S of the E_s values can be observed: $0.67 < E_s < 0.80$.The fluctuations from one point to another reflect the local particular features of strain conditions.

The mean procentual shortening and elongation of the principal axes of pebbles can be graphically deduced on the Wood diagram (Fig. 6). According to the X/Y and Z/Y ratios, reductions of the Z axes perpendicular to S_1 reaching 40%

and elongations of X axes parallel to the extension lineations of ca 60% appear. The flattening strain in the Globu quarry probably reflects also the superposition of a weak tectonic deformation, with an intensity approaching $E_s = 0.5$, a value which is considered to be the limit of tectonic strain.

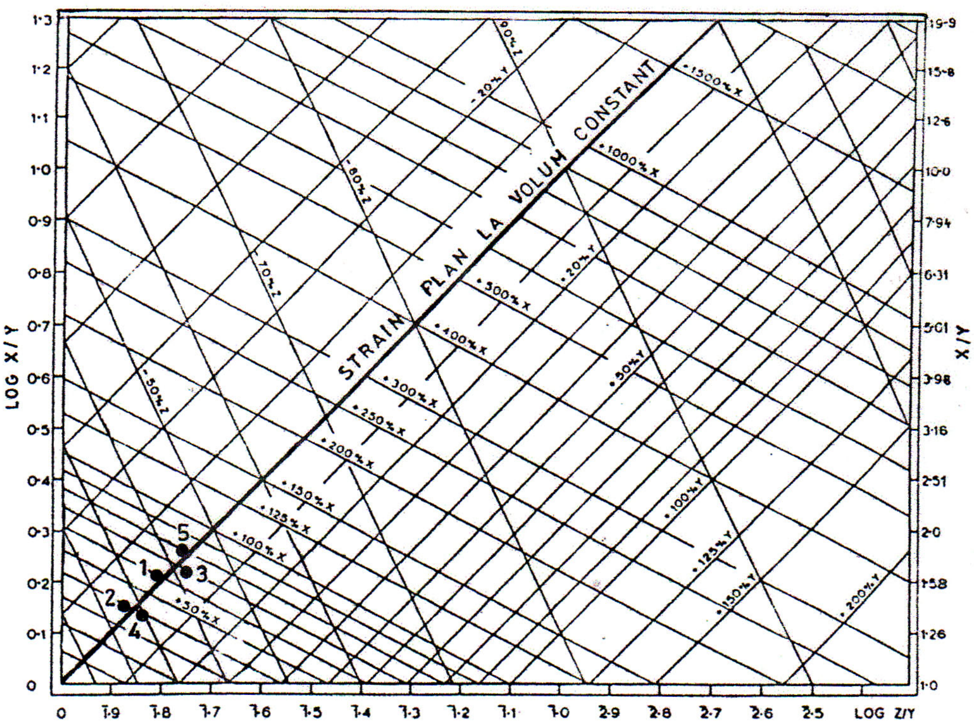

Fig. 6 – Wood diagram.

Due to its generalization degree, the Wood diagram represents the best framework for a rapid comparison between different sets of data. Having this in view we plotted on Fig.6 the mean calculated values of the axial ratios X/Y and Z/Y for metaconglomerates of the Mehadia-Cornereva zone (1), of the Apuseni Mts. (Laminated Conglomerates Formation of the Poiana Nappe (2), of the Infrabucovinic Nappe Permian at Şarul Dornei, East Carpathians (3). We add two examples of the international literature, their authors – Bankwitz, Bankwitz (1989), and Paterson, Sample (1988) having as objects also Permian anchimetamorphic formations from the Thuringian Forest (4), respectively California (5). Besides their age, all these metaconglomerates have in common some structural aspects due to the continuous progressive deformation at the origin of the development of foliation and extension lineation. The final triaxial shape of clasts shows the plane strain as dominant deformational event in all the compared regions.

The low scattering of points on diagram may be seen as an expression of a certain constant deformation imposed by similar local geological conditions, as well as by a similar lithology of the compared formations.

Moreover, for the examples 1, 2 and 3, the similarity is conserved what concerns the strain history, and the microscopic structures identified evidence the dominant character of deformation mechanisms specific for a ductile regime (Dimitrescu, thesis 1998).

4. CONCLUSIONS

1. From the point of view of microscopic analysis, an increase of the deformation gradient from N to S can be inferred, the rocks bearing the clear imprint of plane strain in the conditions of a low-grade metamorphism.

2. The results of strain analysis suggest that in general, the pebbles in the metaconglomerates were deformed and aligned parallel to the direction of maximum extension of the ellipsoid, by a continuous and progressive process imposed by plane strain.

3. Although the deformation of Permian rocks appears slightly heterogeneous as type and weak as intensity, we do not exclude the intervening of ductile tectonic processes in an incipient stage of evolution.

4. As well as in the Apuseni Mts., from our present investigations we conclude that the age of this tectonics may be Alpine.

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