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Different types of echeloned secondary fractures into a zone of shearing as indicator of strain state of this zone

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Echeloned secondary cracks into shear zones are traditional objects of study in structural geology and tectonophysics. Usually such study is basing rightly on postulates of small deformations and stress field examination is using. Many properties of these objects were explained by this path. But secondary fractures in natural shear zones and in experiments not always correspond to each other and to the structures which are theoretically predicted at studying of stress fields. For instance, there is alteration of sets of “R” and “R’ ” cracks along experimental shear zones. Such phenomenon doesn’t exist as clear kind in nature and its explanation is not simple using of stress field. The problem of this investigation is next: what combinations of secondary structures are the possible and forbidden for certain arising strain? This problem was considered from the point of view of strain state of simple shearing zone, instead of studying within the frames of a stress field.

Base model of secondary structures into shear zone was considered after (Hancock, 1985). This scheme was constructed for the stress under simple shear condition, as it was proclaimed. All possible kinds of structures have collected in a single picture without detail analysis what stress (strain) field is in agreement with objects. The examination of 2D stress case shows the existence of next structures. There are extension fractures “e”, secondary shear cracks “R” and “R′ ” also as “X” and “P” (both as pairs structures for 30° and 60° regarding pressure axis orientation). Other 2D structures are: “Y” crack as main fracture (single, not pair) also as stylolites “St” and cleavage “S1”. Such structures as folds “f”, thrusts “t” and normal faults “n” may appear if $\delta 2$ axis (perpendicular to the picture plain) is not neutral. These structures can not appear under condition of mechanical pure shear stress state. Development of folds “f” and thrusts “t” will lead to elongation along $\delta 2$ axis. Normal faults “n” may appear only under shortening along this axis. Joint existence of these two groups of structures is improbable (folds “f” and thrusts “t” contradict to normal faults “n”).

The considerations of the effects of increasing or decreasing of zone width, of increasing or decreasing of block length for 2D strain case, also as increasing or decreasing of volume of part of zone were made (Yakovlev, 2008) using the same types of structures. Sufficient displacements along series of Ridel’s fractures “R” gives the effect of decreasing of width (thickness) of zone, and as a result, it leads to zone elongation under condition of constant volume of zone. Fractures “X” type should have the same effect. These structures (“R” and “X”) are pair in terms of strain under our consideration. Ridel’s fractures “R′ ” are conjugate regarding "R" cracks under stress field consideration. But displacement along fractures “R′ ” produce increasing of shear zone width (thickness) and of its shortening along strike. Fractures type “P” have the same property. Thus fractures “R′ ” and “P” are pairs regarding strain state of shear zone. The fractures type “Y” doesn’t produce a changing of length and width of zone. The stylolites fractures type “St” (usually due to a pressure solution of calcite) are appearing under conditions of decreasing of shear zone volume. Tension cracks “e” (calcite accumulation) denote conditions of volume increasing. Some combinations of these fractures are possible, but some are outlawed. For instance this analysis shows that “R” and “R′ “ fractures cannot to appear together, although they are equal in term of stress analysis. The table below shows some theoretical cases with indication of structures as active, resolved and forbidden one.

	Elongation of zone (reduction of zone width)			Shortening (increase of zone width)		
	3 cases of changes of volume			changes of volume		
	Reduction	Constant	Increase	Reduction	Constant	Increase
active	R, X, St	R, X	R, X, e	R’, P, St	R’, P	R’, P, e,
resolved	Y, e	Y, e, St	Y, St	Y, e	Y, e, St	Y, St
forbidden	R’, P			R, X		

This analysis was used in several cases for explanations of experimental and natural structures and for some predictions of structures appearance.

Case 1. Alternations of domains of shear cracks of «R» and «R′» types are taking place in experiments along shear zone (Stoyanov, 1977). They are interpreted as a combination of domains having elongation and shortening of medium (along zone strike) with a keeping of total length of a zone. There are variations of width of a zone of influence of a faults, observed in natural structures, and changes of amplitudes of displacement in seismogenic faults (Strom, Nikonov, 1999). The assumption was made that these structures have relation to this phenomenon (alternation of domains of development having shear cracks "R" and "R′ " types) i.e. to elongation and shortening of domains along of a fault zone.

Case 2. Structures of the termination of large faults of type "horse tail" and "fur-tree" are interpreted as domains with development of "R" and "P" shear crack as secondary faults under conditions of lengthening and shortening of sides of main fault (Osokina et al., 2007)

Case 3. Shatter zones in detachment of the Vorontsovsky nappe (North-West Caucasus) have relation to shear cracks of "R" type and testify about an elongation of a body of the nappe. There are no cracks of "R' " in the nappe. This result confirms the solution regarding of its geodynamic setting, based on study of folds strain (Yakovlev et al., 2008).

Case 4. Simple shearing zones which are located in massif under condition of pure shearing are especially theoretically studied. Under these conditions the length of shear zones in massif will be elongated or shortened depending on their orientation to an axis of shortening. So, if the strike of zone will be more then 45 degrees with this axis, the secondary cracks should have types "R, X" without "R', P" (condition of zone elongation); and opposite (Yakovlev, 2010).

Results of last case consideration means that it is better to develop the technique of experiments for possibility to increase and decrease the length of a model for study of this aspect of similarity between nature and models. The collecting of such different types of echelon cracks will be useful for understanding of natural conditions of shear zones appearance.

Conclusions.

1) The cracks «R» and «R′» types can't appear in one domain of shear zone because they lead to opposite results of deformation along strike of zone under condition of simple shearing of strain. It takes place despite that these cracks are equal in stress state of pure shearing. 2) Concerning arising deformations of a shear zone, the cracks of «R» and «X» types are pair (due to lengthening of zone along strike) also as cracks «R′» and «P» types are opposite pair (case of shortening of zone length). 3) The table of theoretically possible and forbidden secondary fractures is offered at different deformation conditions of a shear zone. 4) The problem of gathering and ordering of permanent combinations of secondary structures of shear zones on the basis of representation about of strain state of zones was put forward. 5) It was offered to use a change of length of a shear zone at modeling of these structures on equivalent materials as a direction of modernization the technique of experiments.

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