Folded systems of different scales and detection of their formation mechanisms: examples from individual fold to whole Mz-Cz sedimentary cover of the Greater Caucasus

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Hierarchy of the folds systems formation mechanisms

The problem of detection of mechanisms of folds and folded systems formation is complex as strongly depends on the size and type of structures. Quantitative models of such mechanisms (analogical, numerical mechanical or kinematic) may be used effectively as standards. Uniform rules of strain parameters description or of geometry of models and of natural objects are key aspect for use of the formalized procedures of a choice of tested mechanisms during the analysis of natural structures. Some levels of structures in connection with scale of layering are considered: “individual folds” (layers), “domains” (1-2 km width, several folds, package of layers), “structural cells” as large complex folds in scale of whole sedimentary cover (5-7 km width). Geodynamic significance of mechanisms can be found in objects of the last level mainly. Cases studies of different scale structures from Greater Caucasus are offered.

Strain parameters of folds and its application for geodynamic study of local structures

Two methods of individual folds study were constructed for measurements of shortening value and viscosity contrast based on two models (Yakovlev, 2002). The method for study of single viscous layer folds (1978) was based on finite element model (Hudleston, Stephansson, 1973); it was used for study of 78 fold trains in Chiaur zone of Greater Caucasus (shortening values, Sh: 26% ÷ 82%, 56% average, viscosity contrast 2 ÷20, 10.1 in average). The kinematic model of similar folds in alternation of competent and incompetent layers uses numerical repetition of constant increments of buckling and flattening mechanisms. Based on this model diagnostic diagram was compiled (1981) and it was used for study of 36 multilayer folds in the same region (Sh=27% ÷ 83%, 56% average). The correlation of results of two methods application for 8 locale structures of Chiaur zone was high (r=0.94). These methods may be considerably updated on base of recent theoretical results in study of folds mechanics.

The method for multilayer folds analysis was used for study of the Vorontsovsky nappe formation mechanism in Northern-West Caucasus (near of Sochi). Data on geometry of competent layers in 39 folds were collected in a detachment zone of the nappe in the tunnel and shortening values were estimated (2006). Parameters «fold axial surface dip (AX)/fold shortening value (Sh)» were plotted on the scattered diagram (fig. 1, A). These points formed the stretched cloud. For comparison of this trend with two geodynamic mechanisms, models of process of horizontal shortening (pure shearing) and of horizontal simple shearing were constructed (fig. 1, B, C). First model is related in geodynamic sense with lateral pressure from the Greater Caucasus as the active process; the second is associated with gravitational sliding of a nappe body from upraised mountains. These trends sharply differ from each other (fig. 1). Horizontal shearing shows decreasing of folds axial surfaces dip from 45° to 0° and increase shortening value from 0% to 100%. Coincidence of natural folds trend with simple shearing trend shows that the gravitational sliding as origin of this structure is more probable.

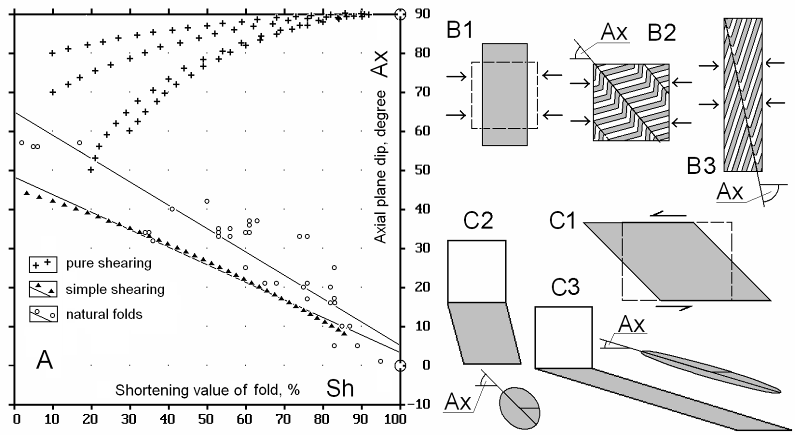

Figure 1: Procedure of choice for detection of Vorontsovsky nappe formation process, scattering diagram is using (A). Trends of strain perturbation for horizontal pure shearing, simple shearing, also as trend of natural folds parameters are shown. B (B1 – B3) – scheme of pure horizontal shearing mechanisms and its two stages. C (C1 – C3) – the same for horizontal simple shearing mechanisms.

Domain geometry is comparing with strain ellipsoid parameters (fig. 2, A): axial plain dip AX, envelope plain dip EN, shortening value (SH'=L_1/L_0, based on interlimb angle). The folding development is traced in 3D space of these parameters as trends using three diagrams (Yakovlev, 1997). Structures of three tectonic zones were studied (fig. 2). Areas of domains parameters points were outlined. These contours have shown coincidence and difference of origin's processes of folded structures. Several geodynamic mechanisms in experimental and numerical kinds (by J.M.Dixon, V.G.Guterman, V.A.Goncharov) were studied (fig. 2, E: 1 – lateral flattening, 2 – accretionary prism formation, 3 – ductile simple shearing in local inclined zones, 4 – pure diapirism in scale of "structural cell", 5 – mesobuckling as combination of diapirism and flattening). Comparison of mechanisms with natural structures (fig. 2, F) has shown that mesobuckling mechanisms (5) in combination with local mechanism (3) is good solution of origin of folding as first assumption in a geodynamic sense.

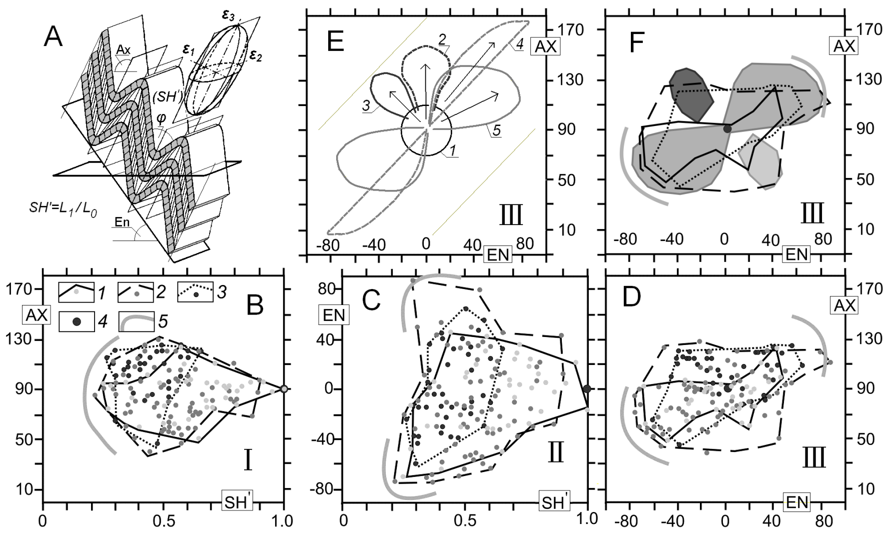

Figure 2: Results of Greater Caucasus folded system study. A – folded domain geometry and strain ellipsoid; B,C, D – natural folded domains on three diagnostic diagrams: 1 – Shakdag zone, 2 – Tfan zone, 3 –Chaur zone, 4 – started point of fold formation process, 5 – front of process; E – contours of points of experimental models (see text); F – comparison of natural structures with models etalons.

References

Hudleston P.J., Stephansson O. Layer shortening and fold shape development in the buckling of single layers // Tectonophysics. 1973. Vol. 17, № 4. P. 299-321.

Yakovlev F.L. The recognition of linear folding mechanisms based on quantitative attributes of it's morphology (on the Great Caucasus example). Moscow. UIPE RAS, 1997, 76 p. (in Russian)

Yakovlev F.L. Investigation of the processes and mechanisms of the plicative deformations development in the Earth's crust (review of the existing approaches) // Tectonophysics today. Moscow. UIPE RAS, 2002. pp. 311-332. (in Russian)