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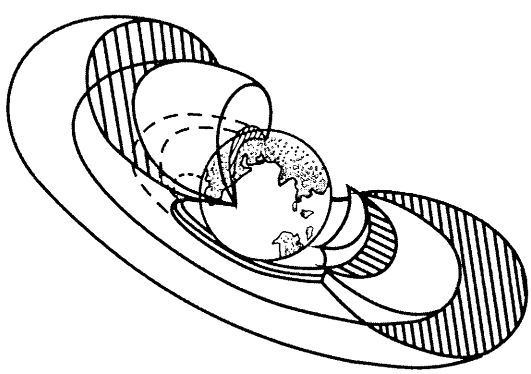

Vladivostok
2005

РОССИЙСКАЯ АКАДЕМИЯ НАУК
ДАЛЬНЕВОСТОЧНОЕ ОТДЕЛЕНИЕ
Тихоокеанский океанологический институт
им. В.И. Ильичева

# ЗАКОНОМЕРНОСТИ СТРОЕНИЯ И ЭВОЛЮЦИИ ГЕОСФЕР

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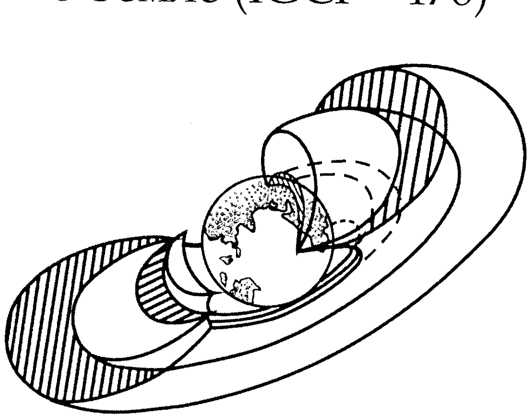

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# APPLICATION OF THE DEFORMATION TENSOR CONCEPTION FOR THE ESTIMATION OF DEFORMATIONS IN DIFFERENT-SCALE FOLDED STRUCTURES

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Natural folded structures are characterized by several (at least seven) of levels of hierarchy; each of them has itself an amount of objects and mechanisms of formation [2]. To characterize the mechanisms of formation of these objects, we should consider the form and orientation of the ellipsoid of deformation (tensor) of their composite smaller-scale parts. Only the combination of these data allows us to obtain the whole notion of displacement vectors and values, i.e., the field of deformations, that allows us to compare this field with model mechanisms. The smallest objects, for which the deformation tensor can be estimated, are parts of layers (rock samples).

The strain ellipsoid, obtained by the strain-analysis of few numbers of thin sections for the rock samples, virtually represents the deformation tensor inside the layer. Strain ellipsoid orientation relatively the bedding and the elements of the folded structure, allows us to determine the elements of the rotation and simple shear along the layer (Fig. 1 a). Usually, the results of the folded structures investigations are limited by the illustration of the distribution of orientations and ratios of the principal axes of the strain ellipsoids and the conclusions of the considerable non-uniformity of deformations. To characterize the deformations of larger structures J. Ramsay proposes to use the strain ellipsoid for determining the initial thickness (and length) of the layer and estimating of horizontal shortening ([4], page 549). Nobody tried to characterize the deformation using the tensor or ellipsoid conception for the single fold as a whole or for larger structures, but this conception allows us to describe the strain-field.

To determine the value of shortening inside a fold, the layer geometry can be used. Usually, the most of folds either considered as concentric type or just ones folds are studied (fold geometry class 1B, according to changes in the layer thickness in the hinge and in the limd with respect to the dip of layer [4], page 349). Therefore, the shortening is calculated as the ratio of the measured length of the layer to its horizontal prolongation. In flysch formation layers, competent layers (classes 1B and 1C [4]) interchanges with incompetent ones (class 3), and form a similar type of folds together ([4], page 353). To characterize the shortening of the layer system in the fold in such structures, we suggest using the kinematic model of the fold formation (Fig. 1a, 1b), that satisfy to the conditions of the geometry of such folds [2, 3]. For simplicity, we consider that the volume of the structure (rocks) is constant in the process of deformation, and that no deformations and displacements occur along the hinge lines of folds, that is, the deformations are plane (2D). In this case, the deformation tensor can be inscribed into the fold structure in the following simple manner. The axis of the maximum shortening is perpendicular to the axial plane of the fold, the axis of the maximum lengthening lies in the axial plane and is perpendicular to the hinge line, and the intermediate axis coincides with the hinge line of the fold (Fig. 1c). The figure (Fig. 1c) shows, that the deformation tensors of the lower level (within the layer) having components of rotation within the competent layer and components of rotation and simple shear for the incompetent layer are related to the deformation tensor of the higher rank through the model, using some simple kinematic mechanisms of the fold formation (bending, bending/simple shear combination and flattening).

In this construction, spatial orientation of geometrical elements of the fold is not important (only for the deformation tensor). To reveal the components of the deformation tensor within the layer package and few folds scales (also for the value of the simple shear for definite directions) the domain geometry can be used. In this case, the domain is a part of the structural cross-section, including one or some number of folds, representing lithological homogeneous layer packages within a uniform tectonic situation (Fig. 1d). Besides the fold shortening (i.e., one of the general component of the deformation tensor), the dip of the axis planes of the folds and the dip of the fold envelope plane are determined [1]. One of the possibilities of accounting for the rotation (and simple shear) components is the domain rotation around the axis, coinciding with hinges lines of the folds up to the position, when the fold envelope plane becomes horizontal. At the next stage, superposition of the horizontal simple shear deformation (along the envelope plane) is used for the domain geometry in such amount that the axial planes acquire the vertical position. During the first stage, the ratio of the lengths of the principal axes of the ellipsoid (tensor) of deformations is not changed, during shearing at the second stage, some change of the ratio of the lengths of the axes of maximum shortening and lengthening occur.

At the third stage, the domain is extended in horizontal direction up to the moment when the deformation ellipsoid becomes a sphere, and the layering returns to its horizontal "pre-folded" position. During these procedures, the initial length and the angle of the dip of the structural cross-section line inside the domain is also changed and change into pre-folded line with certain length and angle of the dip [1, 2]. These procedures finally allow us to reconstruct the pre-folded location of not only one domain, but of a number of domains, successively related to each other. Accounting for the fault planes as the domain boundaries, we can find its initial orientation into the horizontal "pre-folded" layering using the same three operations. If we know the difference of the stratigraphic column position of layers into neighbor blocks, we can determine the vertical and horizontal amplitudes of displacements of the blocks. Therefore, the value of the horizontal shortening of the whole structure may be determined. For three tectonic zones of the Great Caucasus, this method gave the estimates of shortening of 1,6 to 2,2 [1, 2], and allowed to predict the structure of the surface cover-basement up to the depths of 10-25 km, which was confirmed by geophysical data [1, 2]. Some separated folds show the shortening value up to near 10 [3].

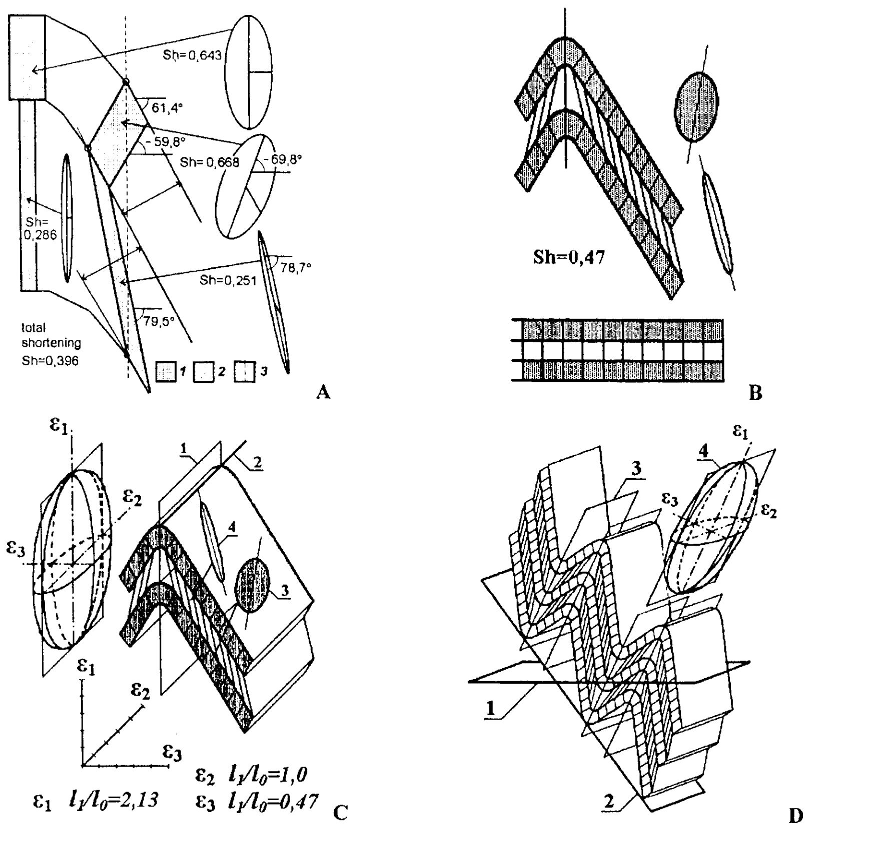


Fig. 1. Deformation characteristics of various scales structures

A - the model of a similar fold in a layer package (according to [2], with changes, 1 - the competent layer, 2 - the incompetent layer, 3 - the axial plane), B - the fold of the competent and incompetent rocks interchange with the respective strain ellipses on the limb (schematic drawing) for the fold shortening value of (Sh=0,47) in the direction perpendicular to the axis plane; the initial position of layering is shown, C - the model of the same fold with the shown ellipsoid of deformations of the fold, reflecting the deformation tensor (its shape and the orientation of the axes), (1 - the axis plane of the fold, 2 - the fold hinge, 3 - the deformation ellipse into the competent layer, 4 - those in the incompetent layer), D - domain geometry (the same folds) and its ellipsoid of deformations (1 - the horizontal plane, 2 - the fold envelope plane, 3 - the axial plane, 4 - the deformation ellipsoid for the domain).

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**Использование концепции тензора деформации для измерения деформаций в складчатых структурах разного масштаба.**
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Предлагается новый подход к количественным геометрическим (кинематическим) моделям деформаций в слое (стрейн-анализ), в отдельных складках пачек слоев (переслаивание компетентных и некомпетентных слоев) и в некотором объеме слоистой среды, заполненной такими складками (домены). Показаны модели образования структур и методики определения деформаций в таком виде, который принят в механике, на всех трех уровнях организации этих структур. При наличии достаточной информации предлагаемый подход обеспечивает однозначное восстановление доскладчатой структуры в масштабе тектонических зон, что позволяет, в свою очередь, прогнозировать складчато-разрывную структуру в размытую часть и в глубину на 10-30 километров (для границ крупных стратиграфических и тектонических блоков). Теоретические разработки дополняются материалами по конкретным структурам Большого Кавказа масштаба от единичных складок (с сокращением до 10-ти раз) до тектонических зон (сокращение от 1,6 до 2,2 раз).