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Development of sheath folds in large-scale plastic deformation

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An approach to stress and deformation has been developed that treats elastic loading (i.e. stress) as a change of state in the sense of the First Law of thermodynamics. The theory uses an equation of state for solids, involves a transformation of the thermodynamic theory from scalar form into vector form, and takes into account that a solid consists of bonded matter. The subject of interest is the mechanical interaction of a thermodynamic system with a surrounding within a larger solid; hence two independent force vector fields exist: the external one is controlled by the boundary conditions, the internal one by the material properties; they are brought into equilibrium with one another by the assumption that in the elastic realm no bonds are broken, and the contact is bonded. It has thus been possible to successfully predict the microstructural properties of simple shear.

Work done during loading can lead to various states of deformation as a function of the external boundary conditions. It is therefore necessary to define an ideal change of state with respect to which all others are compared. As a *first step*, it is thus assumed that the ideal change of state is an isotropic volume change because this type requires maximum work. In a *second step* the external boundary conditions are then relaxed to arrive at the desired deformation configuration (e.g. simple or pure shear, oblate, plane, or prolate strain, etc.). For directions with no finite change of length, the shortening of the unloaded radius due to step 1 must therefore be balanced by a stretch of similar magnitude in step 2. However, whereas the contraction in step 1 is isotropic, the expansion in step 2 is anisotropic and does have identifyable eigendirections. Therefore the spatial properties of step 2 control the properties of stress which is a force vector field. Through a work function the displacement field (in terms of change of radius length as a function of direction in space) is derived from the force field; from the displacement field the strain can be calculated if desired.

At the elastic-plastic transition the state of stress decays irreversibly through breaking of bonds. The transition is connected with a bifurcation: the loaded state can only partially relax into one of two possible states the geometric properties of which have opposite skew. Thus linear elements oriented parallel to X_2 and perpendicular to the X_1X_3-plane (e.g. fold axes) are mechanically unstable; they will passively rotate from either side into the extending eigendirection *e* parallel to X_1, leading to sheath folds. The phenomenon is related to turbulence in viscous flow and the origin of conjugate joint sets in brittle deformation.