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Non-isochoric flow (deformation with non-isotropic volume loss): Mohr circle construction and implications on flow.

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The geometry of structures in deformed rocks is mainly a function of the flow field imposed on the material during deformation. Therefore, two-dimensional plane strain flow can be exactly described by the ratios of pure shear and simple shear components, i.e. the kinematic vorticity number W_k. Nevertheless, this is only the case if no volume increase or volume loss occurs during deformation. Addressing this problem, Passchier (1988) introduced a second variable to describe non-constant volume deformation, the kinematic dilatancy number (A_k), expressing the flow field as a function of rate of volume change, in analogy to the W_k. In the case of isochoric deformation, Mohr circles of flow are centred on the vertical coordinate-axis (ω) in the ε/ω-space (Passchier, 1991). Deviation from isochoric flow results in a shift of the circle centre to the left (volume loss) or to the right (volume increase).

The present study extends the use of a continuum mechanic model to a quantitative description of deformation with non-isotropic volume loss. Thus, a new velocity gradient tensor and the corresponding Mohr circle are introduced. Our model is characterised by a Mohr circle that touches the reference frame in its origin at the position of the stretching eigenvector a_1 (similar to simple shear), but the circle centre lying to the left of the vertical reference axis (volume loss). In fact, our this model only permits shortening parallel to the shortening ISA, but no stretch parallel to the stretching ISA or parallel to a_1. The sum of the double angles of α (the angle between the eigenvectors) and β (the angle between the lines of no instantaneous stretching rate) are always 180° in Mohr space, which is a further special feature of this deformation. It enables to calculate the W_k out of the A_k and vice versa. During ongoing volume loss, the angle between the principle shortening direction and the shortening eigenvector decreases,

hence the W_k also decreases (i.e. the pure shear component increases).

A natural application for this theoretical model was found in thin sections from lower greenschist facies shear zones in the western Tauern Window. The angular relationship between the foliation (which can be argued to be (sub)parallel to the stretching eigenvector of flow, a_1) and a series of stylolites (pointing toward the principle shortening direction ISA), which were inclined into the shear direction, was used to construct the Mohr circle of flow. From this construction, one can easily determine the W_k out of the Mohr diagram. To establish the A_k, the average amount of volume loss was calculated from small veins, which show an apparent offset along the stylolites. This calculation appears to be valid because no precipitation in form of fibrous veins etc. can be found in the xz-plane. The missing precipitation (veins) implies that there is a negligible amount of stretch parallel to the stretching eigenvector (a_1), hence the Mohr circle has to touch the reference frame in its origin at the position of a_1. The value of A_k can then be read from the constructed Mohr circle, as the horizontal distance of the Mohr circle centre to the vertical (ω) axis represents the instantaneous volume change (A), which gives, divided by the stretching rate factor (S), the A_k (Passchier 1991).

This also implies that the volume loss during deformation is non-isotropic, as pressure solution occurs only parallel to the stylolites (= ISA_1). The distinctive feature of this deformation is the existence of an orientation parallel to the shear zone boundary, which is non-rotating and non-stretching (i.e. similar to an eigenvector in simple shear). Nevertheless, this flow has a second non-rotating orientation inclined into the shearing direction, thus excluding a simple shear type of flow. Instead, a non-isotropic volume loss flow type can explain these special qualities

Variations of this flow-type might also be possible under different conditions, e.g. similar flow conditions might occur during soft sediment deformation with non-isotropic volume loss during compaction.

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Passchier, C. W. (1991). "The classification of dilatant flow types." Journal of Structural Geology 13(1): 101-104.