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Flow patterns arising from viscous matrix perturbation due to rigid inclusion rotation under bulk coaxial vs. non-coaxial plane strain: new insights from analogue modelling and implications for use of discriminating shear sense indicators

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The formation of quarter structures depicting an overall monoclinic-like (stair-stepping) symmetry (as defined by Passchier and Trouw, 1996) and associated with matrix flow perturbation caused by rigid particle rotation within a viscous matrix has been recurrently addressed in the literature by a great number of analogue and/or numerical modelling studies (e.g. Ghosh and Ramberg, 1976; Marques et al., 2014 and references therein). However, most of these previous contributions essentially considered bulk non-coaxial homogeneous deformation (i.e. simple shear). As such, the investigated formation of monoclinic-symmetric quarter structures resulting from the interference between the rotating rigid particle and the simultaneous deforming matrix, was mainly considered under rotational flow conditions with vorticity numbers closely equal to one.
In the present work, we carry out a number of analogue modelling experiments in which we systematically consider the comparison of rotating inequidimensional rigid particles within a viscous (PDMS silicone putty) matrix both under non-coaxial vs. coaxial flow deformation (i.e. under bulk plain strain simple shear or pure shear deformation). We show that in both cases rigid rotation from an original position at 45º to the shear plane originates stair-stepping (monoclinic-like symmetric) structures, comprising the rigid particle and the deflection of differently orientated markers in the matrix near opposite quarters of the former, i.e. quarter structures. Thus, in the absence of prior knowledge regarding the deformation mechanism (as is generally the case in face of natural structures at different scales) both these structures can lead to kinematic shear-sense interpretations, which in the case of the coaxial flow (pure shear, irrotational flow) would be wrong. To overcome these potential misconceptions, we use our experimental results to clarify and differentiate in detail the specific flow patterns (i.e. matrix velocity field) forming around the rotating rigid particle either under simple shear or pure shear bulk deformation.
We furthermore use a conceptual example of deformation of boudinaged basic igneous intrusions within carbonate shelf rocks (e.g. in a passive continental margin), to show how our new experimental results are instrumental in differentiating two ensuing possibilities of markedly different tectono-sedimentary evolutions: a) one mainly governed by lithostatic (coaxial) strain flattening e.g. due to continued basin sedimentary infilling/subsidence and implied increment of overall lithostatic load; and b) another one characterized by tectonic inversion of the same margin, under a dominant non-coaxial shear deformation regime.

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