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Review Article

Numerical modelling of porphyroclast and porphyroblast rotation in anisotropic rocks

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A B S T R A C T

The rotational behaviour of rigid objects in a weaker rock matrix during deformation has been the subject of many field, experimental and numerical modelling studies, often centred on the question whether objects rotate or not in non-coaxial deformation. With numerical studies gaining increasing popularity and importance we here provide an overview of the results published so far and provide new simulations. Originally, shape and orientation were investigated, while the emphasis shifted to rheology and slip between object and matrix in the nineties of the last century. Due to improved numerical techniques, anisotropic rheology has become the focus of most recent studies, indicating that it is a primary factor in the rotation behaviour of objects. We present new simulations investigating the role of anisotropy on different scales relative to the object, and show how this influences the rotation rate, as well as the inclusion patterns in case of syntectonically growing porphyroblasts. These simulations show that a variety of factors play a role to determine the rate and sense of rotation of objects. The variability of the inclusion patterns that can develop necessitates extreme caution in the kinematic interpretation of these structures when observed in the field.

Contents

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1. Introduction

Structural geologists use a wide range of structures, such as folds, cleavages, veins, etc., to unravel deformation histories and conditions in rocks (see text books such as Hobbs et al., 1976; Passchier and Trouw, 2005; Ramsay and Huber, 1983, 1987; Vernon, 2004). Hard inclusions (e.g. mineral grains) in a relative weaker matrix form one class of structures that have received much attention for the potential wealth of information stored in them, such as sense of shear, kinematic vorticity number, distinguishing different deformation events, finite strain, etc. (e.g. Passchier and Trouw, 2005, and references therein). The structures related to such hard inclusions fall into two main categories, which we group under the terms *porphyroclasts* and *porphyroblasts* (Fig. 1):

Porphyroclasts are pre-existent hard objects whose shape and orientation can be modified by deformation, resulting in the formation of structures such as sigma- and delta-clasts, and mica fish. Porphyroclasts are relatively hard and occur as large single crystals

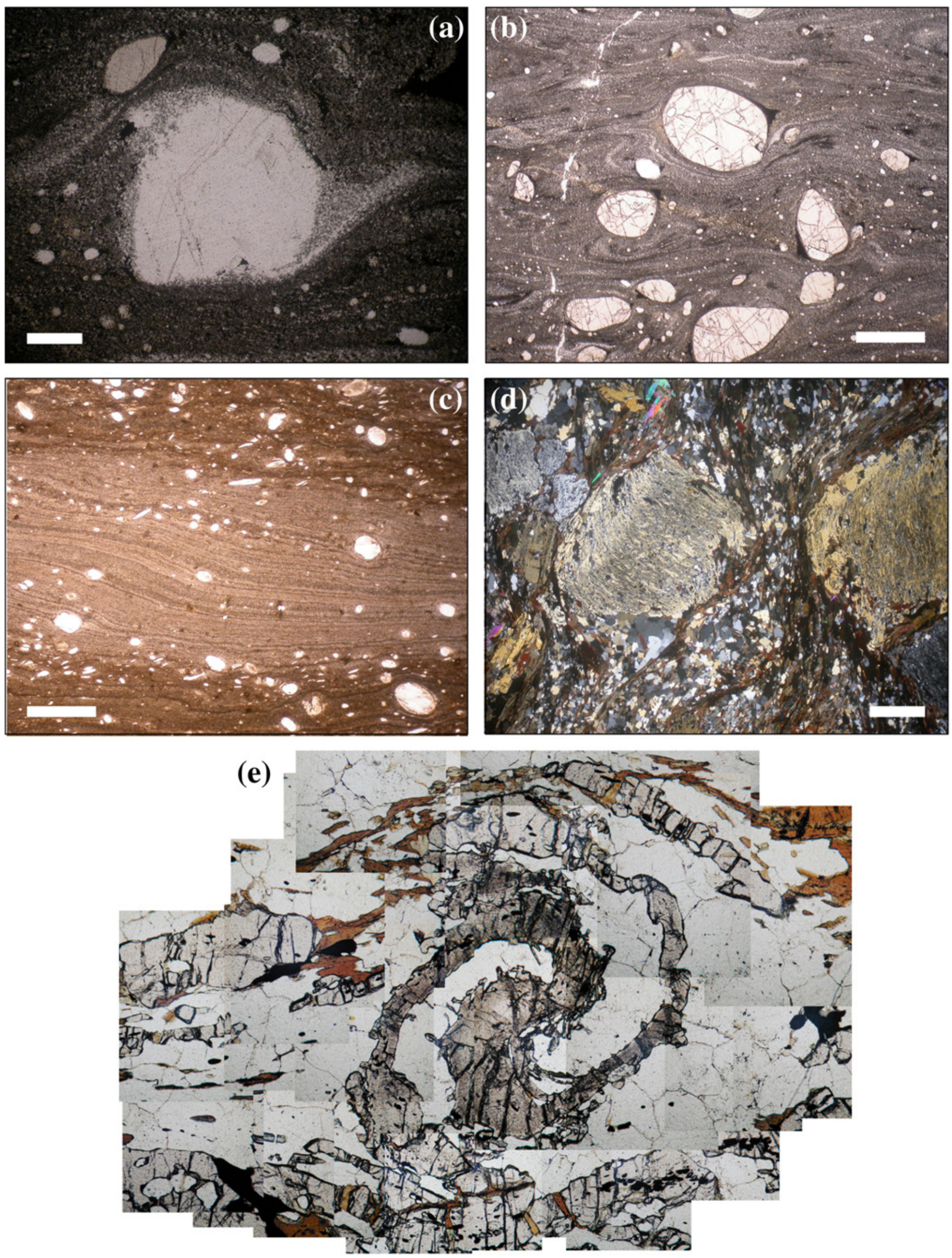

Fig. 1. Examples of porphyroclasts and porphyroblasts: (a) mantled plagioclase δ-clast; (b) interaction between differently sized garnets clasts, decoupling between garnet and mylonite is evident in the central clast; (c) plagioclase and garnet clasts from a mylonite–ultramylonite zone with variable ratios between mylonitic layer thickess and clast size; (d) andalusite porphyroblasts with sigmoidal inclusion pattern oblique to the external foliation; (e) garnet porphyroblast with a spiral shaped inclusion trail or snow-ball inclusion pattern. Photos (a), (b) and (c) are from mylonites zone from the Ivrea–Verbano zone, (d) and (e) are from the Variscan basement of the NE-Pyrenees. Micrograph (e) is courtesy of Joan Reche Estrada (Reche Estrada and Martinez, 2002). White scale bars are 1 mm long. All views are in the *XZ* section with a dextral sense of shear.