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Editorial

Preface: Deformation localization

1. Introduction

The past few decades have seen an intense interest in the localization of deformation in rocks, with especial emphasis on shear zones as a physical expression of strain localization in the mid to lower crustal portions of orogens. The conference on "Shear Zones in Rocks" held in Barcelona in 1979 and organised by J. Carreras, P.R. Cobbold, J.G. Ramsay and S. White, represented a landmark event from the standpoint of recognition of shear zones and associated structures. A key part of that conference was the field trip to the extraordinary outcrops at the Cap de Creus peninsula. Most of the contributions presented at that meeting were included in the Journal of Structural Geology special volume devoted to the conference (Carreras et al., 1980). A subsequent meeting in 1986 introduced methods for kinematic interpretation of the mesoscopic elements of shear zones (Shear Criteria Meeting, Imperial College, London; Cobbold et al., 1987). Those methods have since been employed widely, becoming of central importance to the study of deformation in mid- to deep crustal rocks. The interest in shear zones and localization of deformation has not abated but has even intensified. More recently, international conferences have centered on three-dimensional flow, fabrics and strain (2002 Penrose conference, Ascona, Switzerland; Lebit et al., 2005) and on transport and flow processes in shear zones (2002 joint meeting of the Geological Societies of London, America and Australia, London, UK; Alsop et al., 2004).

There has been significant increase in our knowledge of the processes associated with deformation localization, from field and laboratory studies, from physical and computer modelling, and from theoretical considerations. We know more about metamorphism and geochemistry of shear zones, especially the chemical and physical influence of fluids on deformation, and about deformation mechanisms with regard to microstructural and microfabric development. We now recognize that deformation in many shear zones may depart significantly from simple shear and that flow may be channelled in the crust. Criteria have been developed to establish the degree of non-coaxiality or vorticity of deformation. Improvement has also been achieved in the 3D aspects of deformation zones. The ability to determine the pressure, temperature and timing of flow in various tectonic settings has improved considerably. However, thirty-two years after the 1979 conference, some of the old controversies still continue and also new debates arise from these recent developments.

2. The Geological Society of America Penrose conference "Deformation Localization in Rocks: new advances"

This conference was aimed at bringing together a variety of theoretical and quantitative approaches in the analysis of deformation localization, and "ground truthing" them against direct observations from field geologists. It was highly appropriate to return to Cap de Creus for this conference, which allowed the participants to discuss new ideas on deformation localization in the conference hall and in the field in the wonderful natural field laboratory at Cap de Creus.

The conference was held on 27 June–2 July 2011 in Cadaqués and Cap de Creus peninsula, Catalonia (Spain), and was convened and organized by Elena Druguet (Universitat Autònoma de Barcelona, Spain), Jordi Carreras (Universitat Autònoma de Barcelona, Spain), G. Ian Alsop (University of Aberdeen, Scotland, U.K), Paul D. Bons (Eberhard Karls Universität Tübingen, Germany), Dyanna M. Czeck (University of Wisconsin-Milwaukee, USA), Peter J. Hudleston (University of Minnesota, USA) and Christine S. Siddoway (Colorado College, USA).

The conference, which was attended by more than 70 delegates (Fig. 1), started with a field trip to classic outcrops of shear zones in granitoids, and to a complex high-temperature/high strain zone. The first lecture sessions were dedicated to the geometry and kinematics of shear zones and aspects of shear zone initiation and development. The second field day was spent examining the classic outstanding outcrops along the Cala Serena – Cala Prona shear zone itinerary, which involved active discussion between the participants. In the following lectures, the topic switched to strain localization with regard to metamorphism, fluids and melts and brittle precursors, and to structures and fabrics that are found in shear zones. In the last field session, the participants examined complex shear zones in areas of strong rheological contrast between different rock units in the Tudela area, and the effects of deformation on partial melts and pegmatite intrusions at the Cap de Creus Lighthouse. The final lecture sessions were centered on physical and numerical experiments on strain localization and on orogen-scale localization. The ideas and discussions that came from the conference especially reflect the importance of linking multiple research approaches to understand the processes that lead to strain localization in rocks.

A preliminary edition of the "Illustrated Field Guide to the Geology of Cap de Creus" (Carreras and Druguet, 2013) appeared available for the Conference participants. Apart from including fully illustrated field trip itineraries, this guide provides an overview of

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Fig. 1. Attendees of the Geological Society of America Penrose Conference "Deformation Localization in Rocks: new advances" at Cap de Creus (Spain), posing next to a sheared pegmatite dyke at Cala Serena ravine. Participants are (numbers refer to (b), * refers to participants not present on the picture): Anne-Céline Ganzhorn (*), M.- Gema Llorens (*), Manish Mamtani (1), Dyanna M. Czeck (2), Moonsup Cho (3), John P. Platt (4), Virginia G. Toy (5), Andréa Tommasi (6), Elena Druguet (7), Elisa Fitz Díaz (8), David Iacopini (9), Paris Xypolias (10), Giorgio Pennacchioni (11), Philippe Goncalves (12), Jordi Carreras (13), Manuel Sintubin (14), Sayandeep Banerjee (15), Christine S. Siddoway (16), Emma Soldevila (17), Uwe Altenberger (18), Cees W. Passchier (19), Laurent G.J. Montési (20), Mary Louise Hill (21), Michael Brown (22), Whitney M. Behr (23), Scott Giorgis (24), Laurel B. Goodwin (25), George H. Davis (26), Laura Crispini (27), Yvette Kuiper (28), José María (Txema) Tubía (29), José Sellés-Martínez (30), Juliet G. Crider (31), Micah J. Jessup (32), Dazhi Jiang (33), Daniel S.H. King (34), Walter A. (Bill) Sullivan (35), Nancy A. Price (36), Seth C. Kruckenberg (37), Neil Mancktelow (38), Peter J. Hudleston (39), Adolph Yonkee (40), Katherine Higgie (41), Vasilios Chatzaras (42), Emilien Oliot (43), Ingrid Terricabres (44), Carlos Ponce (45), Gregory Dumond (46), Sharon Carr (47), Lars Hansen (48), Eric T. Goergen (49), A. John Watkinson (50), John W. Cosgrove (51), Joseph L. Allen (52), Christopher Gerbi (53), Sarah Titus (54), Scott E. Johnson (55), Jacqueline Reber (56), Christopher J. Talbot (57), Dani W. Schmid (58), Alain Vauchez (59), Hemin Koyi (60), Tekla A. Harms (61), Stefan M. Schmalholz (62), Åke Fagereng (63), G. Ian Alsop (64), Emily M. Peterman (65), Richard J. Lisle (66), Amanda Getsinger (67), Loic Labrousse (68), Giovanni Capponi (69), Keith Klepeis (70), Domingo G.A.M. Aerden (71), Paul D. Bons (72), sheared pegmatite dyke displaying a pinch-and-swell structure (73).

the various advances that have been made and debates that have emerged based on studies of the Cap de Creus rocks. For instance, the ongoing discussion of shear zones nucleating as buckling instabilities or developing from brittle precursors is based, among others, on Cap de Creus examples. The area has also provided important insights into the complex relations between rock symmetries and kinematics and into the relationships between deformation, metamorphism and magmatism in transpressive regimes.

3. Contents of the volume

The papers enclosed in this special issue are an outcome of the GSA Penrose conference "Deformation Localization in Rocks: new advances". The papers reflect the multifaceted work that is being carried on today on deformation localization, and they do not lend themselves to easy characterization. Nevertheless the Special Issue is arranged in four sections which broadly correspond to the distribution of sessions at the conference.

The first section deals with aspects and new perspectives on the geometry, kinematics and mechanics of shear zones.

3.1. Shear zones: new perspectives on the geometry, kinematics and mechanics

The impact of strain partitioning and of the presence of rheological heterogeneities in rocks are analysed by Carreras et al. through considering field examples from Cap de Creus and deformation experiments. They conclude that the tectonic regime of areas