



Structural diagenesis

S.E. Laubach^{a,*}, P. Eichhubl^a, C. Hilgers^b, R.H. Lander^c

^a Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin, Austin TX, USA

^b Department of Reservoir-Petrology, RWTH Aachen University, 52056 Aachen, Germany

^c Geocosm, 3311 San Mateo Drive, Austin TX, USA

ARTICLE INFO

Article history:

Received 29 July 2010

Received in revised form

27 September 2010

Accepted 2 October 2010

Available online 12 October 2010

Keywords:

Coupled deformation–fluid flow–thermal

transport–chemical reaction

Diagenesis

Fault

Fracture

Mechanics

Rate

Timing

ABSTRACT

Structural diagenesis is the study of the relationships between deformation or deformational structures and chemical changes to sediments. The alliance of structural geology and metamorphic petrology is essential to an understanding of high-temperature deformation. But no such alliance supports research on the increasingly important structural and diagenetic phenomena in sedimentary basins. As papers in this theme section and in recent literature show, such an alliance—structural diagenesis—can help unlock scientific knowledge about the low-temperature realm of sedimentary basins that is of great intrinsic and practical interest.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

An understanding of interactions of structure and diagenesis is increasingly important in a wide range of applications, including predicting the fate of fluids injected deep underground (Stephansson et al., 1996; Tsang, 1999, 2005; Dockrill and Shipton, 2010) and extracting hydrocarbon resources from unconventional, deep reservoirs (Knipe, 1993; Philip et al., 2005; Lander et al., 2008; Olson et al., 2009). Interaction of chemical and mechanical processes is unsurprising in sedimentary rocks that contain hot, reactive fluids and that are subject to dissolution, cement precipitation, and other chemical reactions. In the high-temperature realm of metamorphism, these interactions are so important that metamorphic petrology is a fundamental part of the structural geology curriculum. Indeed, it is essential to the success of structure research, manifest in extensive coverage of metamorphic petrology in the Journal of Structural Geology and frequent contributions of structural geologists to metamorphic petrology literature.

Yet at the other end of the temperature spectrum, in the low-temperature realm of diagenesis (below about 300 °C), systematic

student cross-training in sedimentary petrology and structural geology is rare, owing, perhaps, to decades of petroleum industry focus on shallow parts of sedimentary basins, in which original depositional fabrics may dominate petrophysical properties and structures are rarely penetrative. Although diagenesis, *as defined*, includes both chemical and mechanical processes that affect sediments prior to the onset of metamorphism, much of the literature on postdepositional sediment alteration has focused on chemical processes without reference to structure or mechanics (Milliken, 2003). A review of papers in the Journal of Sedimentary Research (JSR) and Sedimentary Geology and a textbook (Giles, 1997) shows that structures have been mostly overlooked, with the exception of compaction and pressure solution (Bjørlykke, 1999; Gundersen et al., 2002). No paper on the diagenesis of fractures or faults has been published in JSR. Mechanics is neither central to the training of most sedimentary petrologists nor an integral part of their world view. Likewise, in structural geology, diagenetic processes are curiously neglected. For example, as of 2010 only 21 papers in the Journal of Structural Geology (JSG) mention diagenesis in title, abstract, or keywords. A third of these papers are actually about low-grade metamorphism. Only five papers, all published in the last 5 years, cover aspects of diagenesis, compaction, and/or fracture (~0.1% of all JSG papers). The role of diagenesis in fault-rock properties has received attention in JSG and elsewhere (Chester and

* Corresponding author. Tel.: +1 512 471 6303.

E-mail address: steve.laubach@beg.utexas.edu (S.E. Laubach).

Logan, 1986; Knipe, 1993; Hacker, 1997; Vrolijk and van der Pluijm, 1999), such that about half the JSG papers that mention diagenesis concern faults. This work and a growing body of cross-disciplinary research on other topics show increasing awareness of diagenesis as vital, although, in the area of brittle structure, they are neither central to research nor a required part of student training.

This anecdotal evidence suggests that disciplinary barriers need to fall through mutual awareness, cross-disciplinary outreach, and changes in training. Our shorthand for this effort is *structural diagenesis*. The aim is to promote curricular focus on chemical and mechanical processes that affect structures at all scales in sedimentary rocks prior to the onset of metamorphism; application of mechanics to an understanding of diagenetic rock fabrics, particularly in little-deformed rocks; awareness of the impact of chemical processes on the evolution of rock mechanical properties and structures; and appreciation of genetic linkages or feedbacks that apply in some cases between chemical and mechanical processes. Reactions in host rock and associated structures are not necessarily coupled, and in many cases they may not be (Maliva et al., 1995). But we believe that it will be the rare case in which information about diagenesis does not advance structural understanding and vice versa. Papers in this theme section and some that have been published elsewhere arose from a 2004 AAPG Hedberg research conference and a 2008 Geological Society of America session convened by people from both disciplines who have recognized the disciplinary divide and the value of bridging it. As recent work outlined here shows, the fused perspective of structural diagenesis also yields opportunities for solving longstanding structural problems such as dating fault and fracture movement, measuring rate of fracture growth, and locating open fractures. In this paper we provide a brief review to place the papers in the special theme section in context.

2. Examples

Compaction is a topic in which mechanics is yielding insights into diagenetic processes. Compaction of porous clastic sediment or sedimentary rock has been viewed as a predominantly mechanical or coupled mechanical–chemical process (Bjørlykke, 1999). Localization of compaction along pressure solution seams or stylolites, accommodating band-perpendicular or -oblique shortening by solution-precipitation creep, has received consideration from both diagenetic and structural communities in both clastic and carbonate rocks (Sprunt and Nur, 1977; Rutter, 1983; Gundersen et al., 2002). More recently, discussion of these structures and the

related processes of distributed pressure solution and porosity reduction have been extended to include surface-charge differences between adjacent dissimilar grain surfaces in contact, such as mica and quartz (Bjørkum, 1996; Renard et al., 1997; Sheldon et al., 2003; Greene et al., 2009). In contrast to pressure solution, structure localization during predominantly mechanical compaction and resultant formation of compaction bands has only recently been recognized (Mollema and Antonellini, 1996; Schultz, 2009). Eichhubl et al. (in this volume) considered the effect of shear on formation of compaction bands in sandstone and contrasted these structures with shear bands. Shear bands, like compaction bands, which are part of a class of structures collectively referred to as deformation bands (Aydin et al., 2006), have been described in sandstone from a variety of depositional and structural settings (Aydin, 1978; Fossen et al., 2007). Few such bands have been described in mudstone (Byrne et al., 1993). Using high-resolution SEM imaging techniques, Milliken and Reed (in this volume) described porosity reduction in deformation bands in mudstone from the Nankai accretionary prism as a dominantly mechanical process. These studies and microstructure studies in sedimentary rocks having no visible macroscopic structures (e.g., Gomez and Laubach, 2006) suggest that a wealth of spaced and penetrative structural features exists in otherwise undeformed rocks and that much remains to be learned about them through advances in imaging (Fig. 1) and structural petrology.

The study of faults and fault rocks is an area in which diagenesis is yielding insights into structural processes, and vice versa (Knipe, 1993; Vrolijk and van der Pluijm, 1999; Fisher and Knipe, 2001; Fisher et al., 2003; Caine and Minor, 2009; Eichhubl et al., 2009; Mitchell and Faulkner, 2009). Faults have potential for feedback between deformation, fluid flow, chemical reactions, changing rock properties, and thermal gradients (Phillips, 1991; Hobbs et al., 2000; Ireland et al., 2010). Fault-slip and associated fracture may increase or decrease fault-zone porosity and permeability, potentially focusing or impeding fluid flow, perturbing thermal gradients, enhancing or restricting reactions and transport of chemical components, and altering porosity, permeability, mineralogy, texture, and mechanical properties of fault and host rock (Chester et al., 1993; Sibson, 1996; Muchez and Sintubin, 1998; Eichhubl and Boles, 2000a, b; Tenthorey et al., 2003; Woodcock et al., 2007). Although it is beyond our scope to review fault-diagenesis literature, two papers in this theme section contribute to our understanding of the role of diagenesis in fault systems. Solum et al. (in this volume) showed that fault-related clay minerals formed largely as a result of cement deposition rather than through

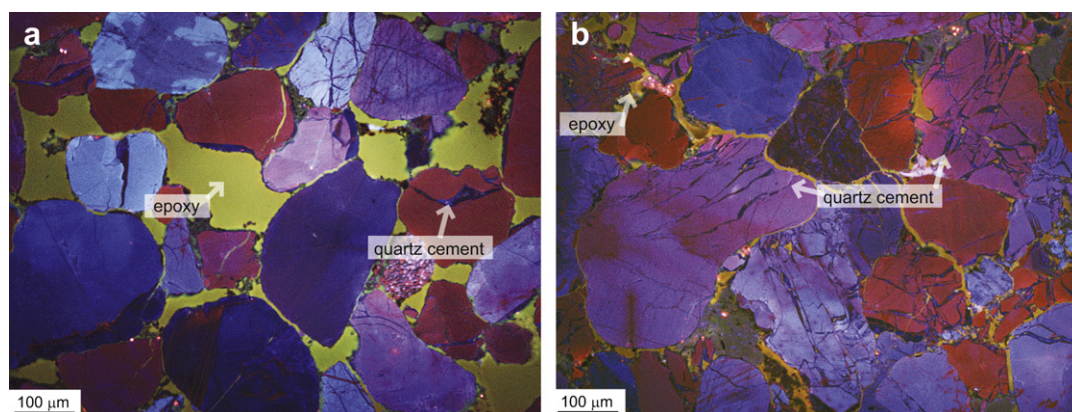


Fig. 1. SEM-cathodoluminescence (CL) images of (a) host rock and (b) deformation band Jurassic Aztec Sandstone, Valley of Fire, NV. Deformation band, b, contains a higher abundance of quartz-cemented microfractures (dark-blue CL color) than surrounding sandstone, a, reflecting greater propensity of quartz to precipitate on fresh fracture surfaces compared with detrital grain surfaces.

Download English Version:

<https://daneshyari.com/en/article/6445158>

Download Persian Version:

<https://daneshyari.com/article/6445158>

[Daneshyari.com](https://daneshyari.com)