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Quartz types, authigenic and detrital, in the Upper Cretaceous Eagle Ford Formation, South Texas, USA

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ABSTRACT

Lithologic heterogeneity of the Eagle Ford Formation in South Texas arises from mixing of extrabasinal grains of siliciclastic composition with intrabasinal grain assemblages composed dominantly of marine carbonate with a lesser component of biosiliceous debris. Detrital quartz in particular is derived from both extrabasinal and intrabasinal sources, posing a challenge for the use of bulk compositional data for mudrock classification. Extrabasinal detrital quartz supplied along a major axis of siliciclastic influx, the Woodbine depositional system of East Texas, is reduced to a minor part of the grain assemblage in South Texas. Petrographic evidence and point-count results indicate that around 85 percent of total quartz in these rocks, equal to about 12.6 volume percent, is authigenic. Thus, significant quantities of authigenic silica are not restricted to siliceous mudrocks, but can be found in carbonate-rich mudrocks as well. Formerly opaline skeletons of radiolaria, the dominant source of silica for authigenic quartz precipitation, are only poorly preserved by replacements including calcite, dolomite, pyrite, and quartz. Dissolved silica released by dissolution of radiolarians, and perhaps also by volcanic glass dissolution is re-precipitated in a variety of forms, including matrix-dispersed microquartz cement, fillings within primary intragranular pores, and grain replacement of both calcareous and siliceous allochems. The mass balance of dissolved silica mobilized from radiolarians and other reactive silicates and the precipitation of authigenic quartz is uncertain because the initial volumes of now-dissolved detrital material versus the final volume of authigenic material (quartz and other authigenic silicates) cannot be determined with accuracy.

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1. Introduction

Understanding of lithologic, textural, and chemical variation in mudrocks continues to be refined, but it is clear that mixing of extrabasinal and intrabasinal sources of detritus is an important control on mudrock heterogeneity (Aplin and Macquaker, 2011; Macquaker and Jones, 2002; Macquaker et al., 2014; Milliken, 2014; Milliken et al., 2012; Schieber and Zimmerle, 1998). Extrabasinal detritus, primarily transported into basins via fluvial axes and to a lesser extent by eolian transport, includes material derived from crystalline rocks of the upper crust, older sedimentary rocks (including recycled organic matter), and weathering products. Intrabasinal detritus forms within the basin of the deposition as planktic or benthic grains, and consists of skeletal fragments, sediment aggregates, and organic matter.

Quartz is one of the dominant minerals in both the extrabasinal and intrabasinal fractions of muddy sediments (Blatt and Schultz, 1976; Dean et al., 1985; Potter et al., 2005). Quartz also occurs in a variety of diagenetic forms in mudrocks (Isaacs, 1981; Kastner et al., 1977; Keene and Kastner, 1974; Milliken, 2013; Milliken and Day-Stirrat, 2013; Milliken et al., 2012). The specific form of authigenic quartz has significant implications for mechanical rock properties. Quartz in the form of grain-binding cement, as opposed to other diagenetic forms such as grain replacements, can impart lithification that causes brittle behavior in both natural and induced deformation (Milliken, 2013). Because mudrock quartz displays such variability in origin and form, measurement of bulk quartz content is of limited use for the determination of sediment source and rock property evolution (chemical and mechanical). Assessment of the character of quartz in mudrocks can only be accomplished by petrographic inspection.

Here, we examine the nature of quartz in the Eagle Ford Formation of South Texas. As will be shown in the following sections, much of the quartz in this unit occurs as clay-size crystals (<4 μm) dispersed together with clay-size clay minerals and clay-size carbonate within the

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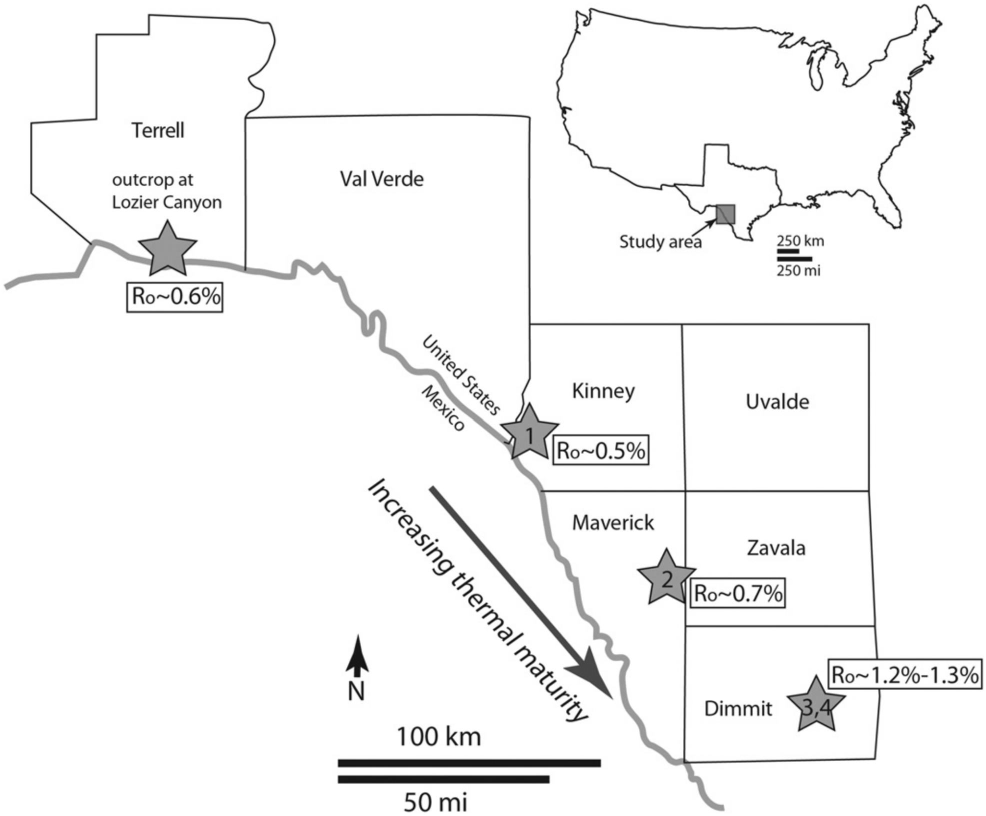

Fig. 1. Location map of outcrops and cores used in this study. Modified from Pommer and Milliken (2015). Thermal maturity at Lozier Canyon is estimated from T_{max} data reported in Romero (2014); thermal maturity in outcrops near Well 1 is reported as 0.53 by Slatt et al. (2012).

mudrock matrix. The generally small size of these crystals greatly limits what can be learned about them using conventional petrographic light microscopy. Discrimination of detrital[3] versus authigenic origin of the quartz depends upon the use of field-emission SEM-based X-ray mapping and cathodoluminescence imaging. The principal finding of our investigation is that quartz in the South Texas Eagle Ford is primarily authigenic material that has formed in response to diagenetic recycling of opaline silica originally deposited as radiolarian debris. Authigenic microquartz can be an important constituent not only within siliceous mudrocks but also within carbonate-rich mudrocks such as those found in the Eagle Ford Formation.

2. Geologic setting

The Cenomanian–Turonian Eagle Ford Formation in the Maverick Basin of South Texas is a mixed siliciclastic/carbonate unit (Dawson, 2000; Donovan and Staerker, 2010; Harbor, 2011; Lock, 2014; Tian et al., 2012; Workman and Grammer, 2013). Deposition of the Eagle Ford Formation took place on a broad shelf during the maximum transgression of the western interior seaway (Donovan and Staerker, 2010; Lowery et al., 2014). Sediment sources include river-dominated deltas that prograded from the north and northwest across the marine shelf of East Texas (Surles, 1987). The San Marcos Arch formed a topographic high between the adjacent East Texas and South Texas basins (Phelps et al., 2014). The East Texas Basin contrasts with the South Texas Basin in terms of the detrital assemblage, which in South Texas contains a more limited amount of siliciclastic influx as a consequence of sediment blocking by the San Marcos Arch (Jennings and Antia, 2013; Ozkan et al., 2014).

3. Sampling and methods

Forty-eight samples from the South Texas Eagle Ford Formation (Fig. 1; Tables 1 and 2) were thin-sectioned for this study. Samples were collected from one outcrop at Lozier Canyon (Donovan et al., 2012), and from four cores: a low-maturity well (Well 1; reported as Iona-1 well in Eldrett et al., 2014), a medium-maturity well (Well 2), and two high-maturity wells (Wells 3 and 4). The character of pores in this sample set (excluding the Lozier Canyon samples) is reported in Pommer and Milliken (2015).

Imaging techniques applied in this study include conventional polarizing transmitted-light microscopy, light microscope-based cold-cathode cathodoluminescence (CL), and field-emission scanning-electron microscopy (FE-SEM; an FEI Nova NanoSEM 430). The FE-SEM data set includes secondary-electron (SE) and back-scattered electron (BSE) imaging, X-ray mapping by energy-dispersive spectroscopy (EDS), and scanned cathodoluminescence (CL) imaging.

Table 1
Distribution of thin-sectioned samples across the outcrop and 4 wells used in this study. See Fig. 1 for sampling locations.

Location	Number of samples	Depth range (m)
Lozier Canyon	8	Outcrop
Well 1	18	57–152
Well 2	7	911–973
Well 3	4	2525–2557
Well 4	11	2775–2811
Total	48	

[3] This paper applies the term 'detrital' broadly to indicate the grain component (primary particulate debris, detritus) regardless of grain origin, extrabasinal or intrabasinal.

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