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ORIGIN AND DISTRIBUTION OF DOLOMITE IN PERMIAN ROTLIEGEND SILICICLASTIC SANDSTONES (DUTCH SOUTHERN PERMIAN BASIN)

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ABSTRACT: Dolomite is a common and volumetrically important mineral in many siliciclastic sandstones, including Permian Rotliegend sandstones (the Slochteren Formation). These sandstones form extensive gas reservoirs in the Southern Permian Basin in the Netherlands, Germany, Poland, and the UK. The reservoir quality of these sandstones is negatively influenced by the content and distribution of dolomite. The origin and the stratigraphic distribution of the dolomite is not yet fully understood. The aim of this study is to identify the origin of carbonate. The main methods used to achieve those aims are a combination of thin-section petrography, scanning electron microscopy (SEM and EDX), and XRD analyses.

The present study shows that the typical dispersed occurrence of the dolomite is a consequence of dispersed detrital carbonate grains that served both as nuclei and source for authigenic dolomite cement. The dolomite cement formed syntaxial outgrowths and overgrowths around detrital carbonate grains. The study also shows that dolomite cement, often in combination with ankerite and siderite, precipitated during burial after mechanical compaction. Most of the carbonate grains consisted of dolomite before deposition. The carbonate grains were affected by compaction and pressure dissolution, and commonly have no well-defined outlines anymore.

The distribution of dolomite cement in the Rotliegend sandstones was controlled by the presence of stable carbonate grains. Due to the restricted and variable content of carbonate grains and their dispersed occurrence, the cement is also dispersed and the degree of cementation heterogeneous.

Our findings have important implications on diagenesis modeling. The presence of detrital carbonate excludes the need for external supply by any large-scale advective flow of diagenetic fluids. By knowing that the carbonate source is local and related to detrital grains instead of being externally derived from an unknown source, the presence of carbonate cement can be linked to a paleogeographic and sedimentological model.

INTRODUCTION

Carbonates are some of the volumetrically most important authigenic minerals in siliciclastic sandstones (Giles et al. 1992; Kantorowicz et al. 1987; Morad 1998; Dutton et al. 2002) and therefore can exert major control on reservoir quality (Saigal and Bjørlykke 1987; Dutton et al. 2002; Dutton 2008), especially in marine sandstones. Carbonate-cemented, continental Permian Rotliegend sandstones (Slochteren Formation) form extensive gas reservoirs in the Southern Permian Basin (cf. Ziegler 1990) in the Netherlands, Germany, Poland, and the UK (Van Wijhe et al. 1980). In these Rotliegend quartzose sandstones, which formed under arid climate conditions, dolomite is a common component often intergrown with ankerite and siderite, whereas calcite is rare (Gaupp and Okkermann 2011; Amthor and Okkermann 1998; Gaupp et al 1993). Dolomite is considered a main authigenic and cementing material (Pye and Krinsley 1986; Amthor and Okkermann 1998) in addition to quartz and clay-mineral cements (Glennie et al. 1978; Gaupp and Okkermann 2011). In carbonate-cement-bearing sandstones of the Rotliegend the porosity ranges from tight to about 25% (see also Gaupp and Okkermann 2011; Nagtegaal 1979). A high content of dolomite typically implies low reservoir quality (Amthor and Okkermann 1998).

Some authors favor an early origin of the dolomite cement in the Rotliegend sandstones (Drong 1979; Goodchild and Whitaker 1986; Purvis 1992; Lippmann 2012), whereas others assume that all carbonate and/or at least the iron-rich carbonate minerals formed during burial diagenesis (Hancock 1978; Pye and Krinsley 1986; McNeil et al. 1998; Lippmann 2012). Several models have been proposed to explain dolomite precipitation in Rotliegend sandstones. Much of the dolomite, Fe-dolomite, and ankerite is inferred to be sourced by external fluids in a repeatedly open system, such as fluids related to adjoining shale intervals or to fault systems (Calvo et al. 2011). Another common interpretation is early diagenetic precipitation near the groundwater level (Amthor and Okkerman 1998; Gaupp and Okkermann 2011). The existing models do not help to predict the distribution of carbonate cement and its influence on reservoir quality. The multitude of inconsistent, explicative models with respect to timing of processes, paragenetic relations, sources for cements, and supply mechanisms in fact hinders predictive modeling. If true, all cases are unique, and site-specific parameters control dolomite cementation. This would limit any hope for the development of more predictive general carbonate cementation models.

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