Marine and Petroleum Geology 78 (2016) 196–221

Contents lists available at ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

Research paper

Diagenesis and reservoir properties of Middle Jurassic sandstones, Traill Ø, East Greenland: The influence of magmatism and faulting

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ARTICLE INFO

Article history:
Received 11 March 2016
Received in revised form
16 September 2016
Accepted 19 September 2016
Available online 20 September 2016

Keywords:
Diagenesis
Magmatism
Sandstones
Reservoir properties
Middle Jurassic
East Greenland

ABSTRACT

The *c.* 500 m thick Middle Jurassic sandstones of the fluvial Bristol Elv and marine Pelion Formations of the East Greenland Basin are evaluated here in order to improve the understanding of the processes that influenced the diagenetic evolution. The study may help to predict the reservoir properties of sandstones affected by magmatism and faulting, both in general and specifically in undrilled areas on- and offshore East Greenland and, in the Vøring Basin on the Mid-Norwegian shelf. The study shows a variety of authigenic mineral phases dominated by quartz cement, carbonate cement, illite and iron-oxide. One of the clear differences between the two formations is the presence of early carbonate-cemented horizons in the marine sandstones; these horizons are inferred to reflect a primary concentration of biogenic clasts and fossil shells. Intense quartz cementation occurs primarily in the fluvial sandstones but the marine sandstones are also highly quartz-cemented. Two episodes of burial and uplift are recorded in the diagenetic sequence and widespread grain-crushing in coarse-grained intervals is believed to result from overpressure and subsequent compaction due to sudden pressure release along major faults. Maximum burial depths may only have been around 2000–2500 m. Cathodoluminescence analyses show that grain crushing was followed by intense quartz cementation. The quartz cement is to a great deal believed to have formed due to increased surface area from crushing of detrital quartz grains, creating fresh nucleation sites for the quartz. Cathodoluminescence investigations also show that only minor pressure dissolution has taken place between detrital quartz grains and that the ubiquitous quartz cementation displays several growth zones, and was thus in part the result of the introduction of silica-rich extra-formational fluids related to the flow of hot fluids along reactivated faults and increased heat flow and temperature due to magmatism. This interpretation is supported by fluid inclusion homogenization temperatures between 117 and 158 °C in quartz cements. In one of the two study areas, the development of macroscopic stylolites has significantly enhanced quartz cementation, probably in connection with thermal convection flow. As a result of the magmatic and fault-related quartz cementation and illitization, the reservoir quality of the sandstone formations deteriorated and changed drastically.

1. Introduction

Since the 1970s, Middle Jurassic sandstones in East Greenland have been thoroughly studied, both as analogues for the prolific Jurassic sandstone oil reservoirs in the North Sea and on the Norwegian shelf and locally as large exhumed hydrocarbon traps. The petrography, diagenetic development and reservoir characteristics of these sandstones are, however, presented here for the first time. The sandstones crop out for over 400 km north-south in the sedimentary basins of East and North-East Greenland (Surlyk et al., 1973; Surlyk, 1977). They comprise the Bristol Elv, Pelion and Olympen Formations, which on Traill Ø are known only from the eastern part of the island (Figs. 1 and 2). Due to block tilting, crest erosion and subsequent sealing by mud-dominant formations, the Bristol Elv and Pelion Formations can be considered as exposed examples of hydrocarbon plays; the sandstones are similar both in tectonic context and facies development to Middle Jurassic reservoir sandstones in the North Sea and on the Norwegian shelf and are thus of considerable interest as oil field analogues. Indeed, these formations have been interpreted to form palaeo-oil reservoirs in the Traill Ø region (Price and Whitham, 1997).

Until now, analogue studies have primarily focussed on sedimentary facies and structural geology, without any thorough

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http://dx.doi.org/10.1016/j.marpetgeo.2016.09.017
0264-8172/

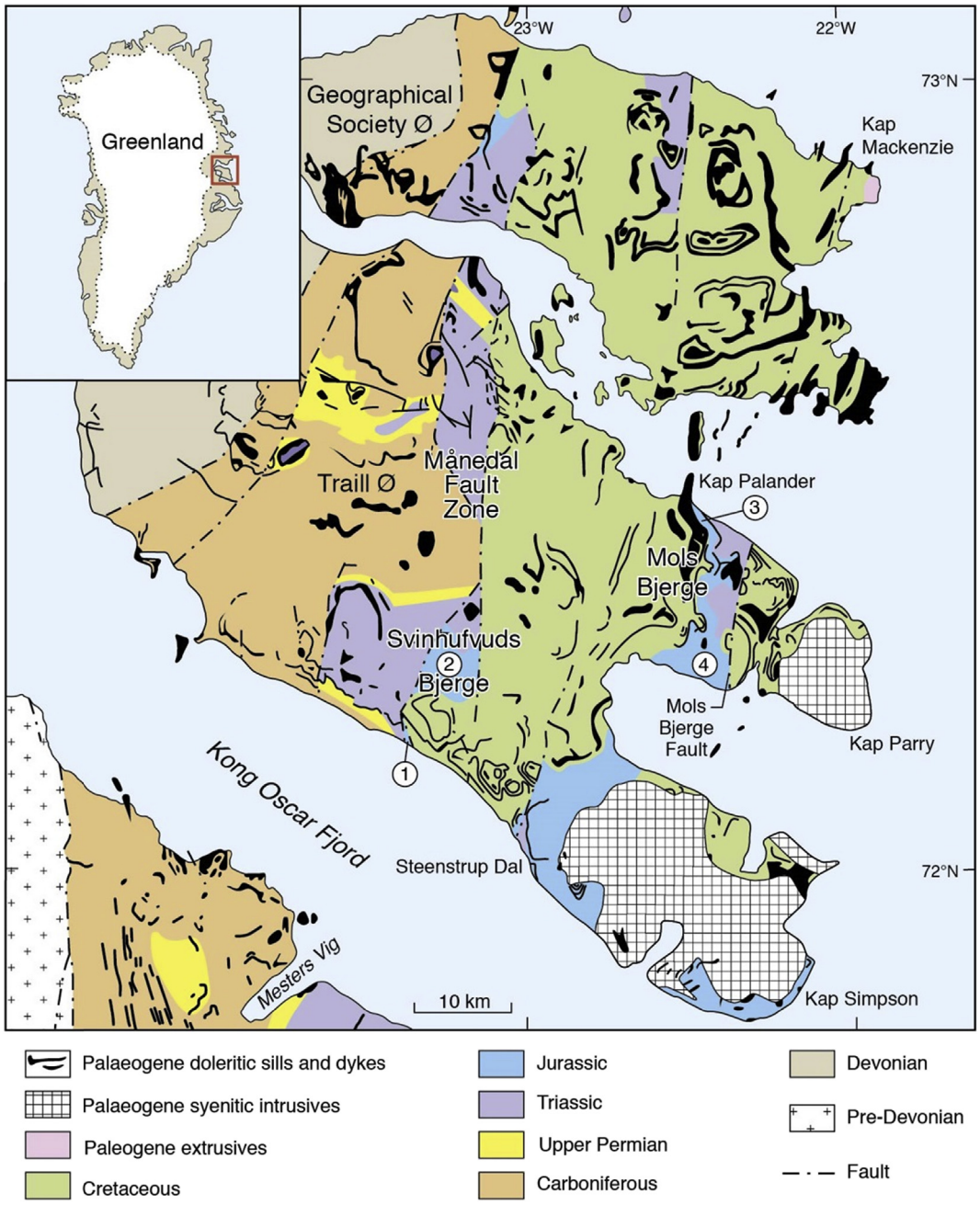

Fig. 1. Simplified geological map of Traill Ø and surrounding areas. Localities on Traill Ø: 1, southern Svinhufvud Bjerge; 2, north-eastern Svinhufvud Bjerge; 3, northern Mols Bjerge; 4, southern Mols Bjerge. Modified from Koch and Haller (1971).

diagenetic examination of the sediments. The present paper outlines for the first time the diagenesis of the Middle Jurassic sandstones on Traill Ø, East Greenland, focussing particularly on the influence of magmatism and fault activity. The study is based on thin section petrographic analyses, supported by X-ray diffraction (XRD), scanning electron microscopy (SEM), energy dispersive X-ray analysis (EDX), cathodoluminescence (CL) and fluid inclusion analyses on quartz cement. The relationships between compaction, cementation and porosity are discussed. Differences in diagenetic development between the fluvial and the marine sandstones and between the two geographic localities are evaluated to better understand facies and burial control and how magmatism and faulting has influenced diagenesis and the resultant reservoir properties. The study hereby outlines the possible consequences for sandstone reservoirs if situated in proximity to magmatic intrusions.

2. Regional geology

During latest Triassic – Early Jurassic time, the Traill Ø area was subaerically exposed and eroded due to uplift. Middle Jurassic sediments, resting unconformably on Triassic sediments (Figs. 2 and 3) were deposited during a regional transgression resulting in the formation of a thick sand-dominated succession (Donovan, 1953; Surlyk, 1977; Stemmerik et al., 1996, 1997; Price and Whitham, 1997; Larsen et al., 1998). In Jameson Land, south of Traill Ø, the Middle Jurassic Pelion and Fossilbjerget Formations thicken from 50 m in the south to about 475 m in the north over a