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Research paper

Early diagenetic formation of carbonates in a clastic-dominated ramp environment impacted by synsedimentary faulting-induced fluid seepage – Evidence from the Late Jurassic Boulonnais Basin (N France)

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ABSTRACT

The Late Jurassic deposits of the Boulonnais area (N-France) represents the proximal lateral-equivalent of the Kimmeridge Clay Formation; they accumulated on a clastic-dominated ramp subject to synsedimentary faulting in relation with the northward propagation of the Atlantic rifting. Within the terrigenous accumulations, some carbonate objects are visible at various conspicuous levels: oyster patch reefs and fine-grained carbonate beds, either continuous, or more or less nodular. Preliminary studies demonstrated that the carbonate beds of the Bancs Jumeaux Formation as well as the carbonate matrix of the oyster patch reefs are of diagenetic origin. In this paper, we extend the study to many other limestone beds of the Boulonnais with mud- or wackestone texture, examining facies and microfacies through various techniques as well as geochemical data (O, C and S stable isotopes, major and trace elements). We conclude that all examined carbonate bodies are of early diagenetic origin and that they precipitated at, or close to, the sea bed, from seawater mixing with ascending fluids containing isotopically light carbon of organic origin. Fluid circulation was probably induced by the extensional block-faulting segmentation of the northern margin of the Boulonnais Basin in Late Jurassic times. Fluid seepages were either channelized along fault planes or more diffuse, as illustrated by the model we propose.

1. Introduction

Fluid flow is a first-order feature of the evolution of basins, in that fluids may interact with sediments during earliest stages of deposition, conditioning both early and late diagenesis. It is all the more important for basins undergoing extensional tectonics where synsedimentary faults drive fluid circulations contemporaneously with sediment accumulation. These aspects are of cornerstone importance for petroleum systems. The geological formations of the Late Jurassic times (Kimmeridgian–Tithonian) crop out along the Boulonnais cliffs (Strait of Dover, Northern France; Fig. 1A and B). They represent a proximal, lateral equivalent of the Kimmeridge Clay Formation (famous major petroleum source rock) and they accumulated in a clastic-dominated ramp environment subject to dominantly aerobic conditions with some episodes of dissolved oxygen restriction (suboxic conditions) favorable to organic-rich deposition (Ramanampisoa et al., 1992; Proust et al., 1995; Deconinck et al., 1996; Wignall and Newton, 2001; Williams et al., 2001; Tribovillard et al., 2001, 2004, 2005; Al-Ramadan et al., 2005). The Boulonnais is a good, small-dimension model of petroleum systems, comprising: 1) fine-grained, clay-dominated, organic-rich formations (termed "Argiles" in the local terminology, e.g., the Argiles de Châtillon Formation) acting as source rocks; and 2) coarser-grained, sandstone-dominated formations (termed "Grès", e.g., the Grès de Châtillon Formation), acting as possible

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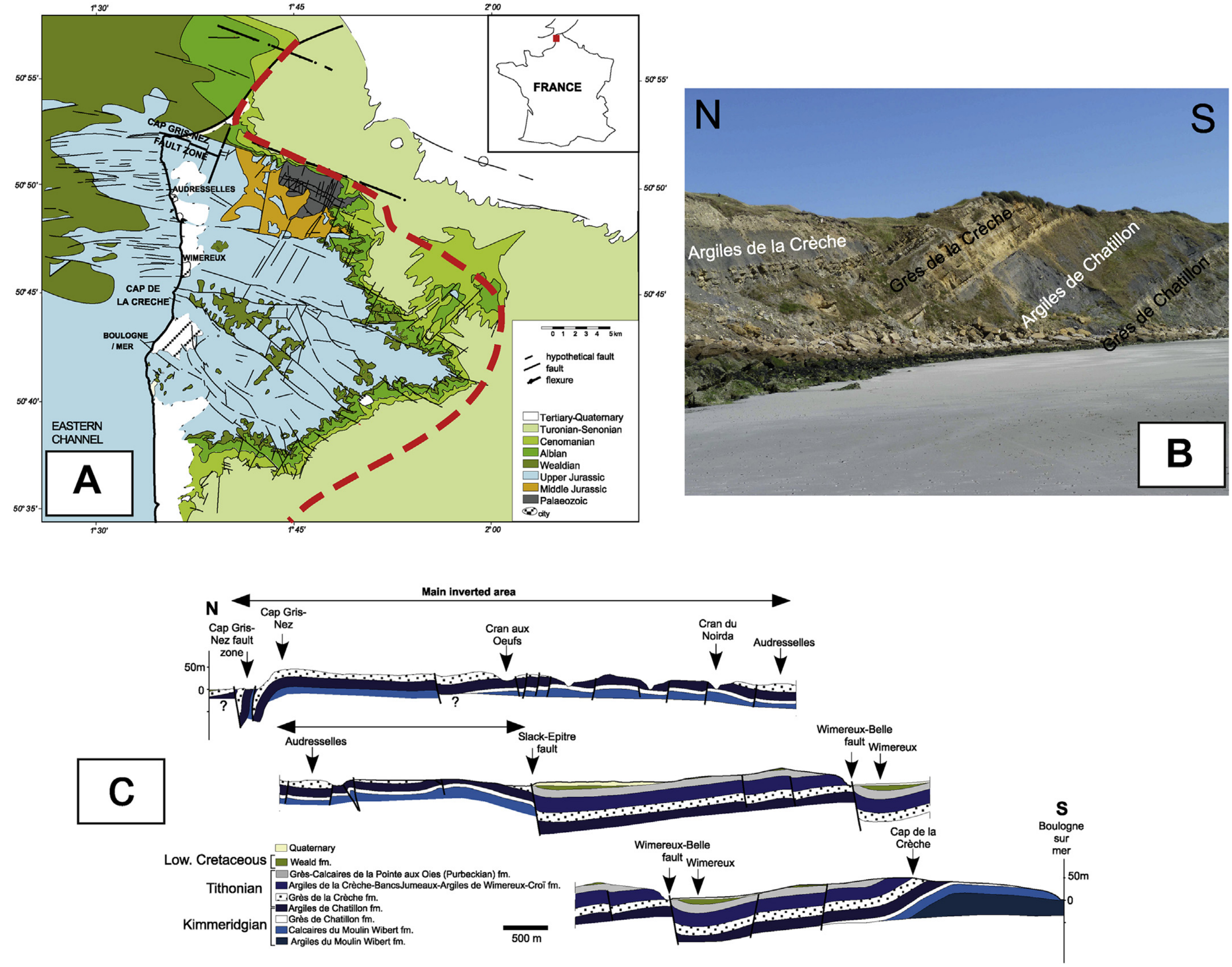

Fig. 1. A: Geological map depicting the general structural and stratigraphical framework of the Boulonnais Basin. The study area corresponds to outcrops of Upper Jurassic rocks exposed along the cliffs from the Cap Gris-Nez fault zone to the city of Boulogne-sur-mer. The red dashed line correspond to the extent of the Jurassic deposits below the Mid-Upper Cretaceous post-rift transgressive sequence. B: Photograph of the Cap de la Crèche section (reference section) illustrating the general clastic-dominated sequence (alternation of sandstone and marlstone formations) characteristic for the Late Jurassic series of the Boulonnais Basin. C: North-South cross section along the cliffs from the Cap Gris-Nez to Boulogne-sur-mer. Note the segmentation of the basin by WNE-ESE trending normal faults coeval with the basin development and the inversion of this fault pattern along localized corridors (mostly along the northern border fault zone, Cap Gris-Nez area). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

reservoir rocks. On a structural point of view, the study area forms the eastern tip of the Weald-Boulonnais basin crossing through the English Channel along a general E–W direction. During the entire course of the Late Jurassic, this basin, alike the Wessex and the North Sea basins, was affected by synsedimentary faulting in relation with the northward propagation of rifting along the Atlantic Ocean (Butler and Pullan, 1990; Underhill and Paterson, 1998; Beeley and Norton, 1998; Newell, 2000; Taylor and Sellwood, 2002; Hansen et al., 2002; Mansy et al., 2003; Minguely et al., 2010; Fig. 1C). This block-faulting geometry had a significant imprint on the subsidence pattern in the basin and, hence, on the depositional contexts. Recent studies suggested that synsedimentary tectonics induced fluid circulations through this incipient petroleum system, favoring diagenetic precipitation of carbonate beds or isolated bodies (namely, oyster patch reefs), through bacterial activity stimulation (Tribovillard et al., 2012; Hatem et al., 2014). In the present paper, the study is extended to many other carbonate beds throughout the Late Jurassic of the Boulonnais, in order to encompass the various types of limestone beds that are encountered there. The occurrence of such carbonate beds is puzzling and sometimes difficult to interpret on the grounds of the sole sediment accumulation arguments: how can the presence of fine-grained limestone beds be explained when they are intercalated within such a clastic-dominated succession? The objective of the study is to determine whether all the carbonate beds (or bodies) included in this Late Jurassic succession are of (early) diagenetical origin (except for the coquina oyster beds that are storm-induced lumachelles; Fürsich and Oschmann, 1986). To that end, facies and microfacies examination, together with geochemical analysis (elemental content and stable isotope composition) have been conducted. Then emphasizing the tectonic framework, we propose a model linking the formation of the carbonate objects to synsedimentary, fault-induced, fluid circulations.