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Oyster patch reefs as indicators of fossil hydrocarbon seeps induced by synsedimentary faults

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ABSTRACT

The Late Jurassic deposits of the Boulonnais area (N-France) represent the proximal lateral-equivalent of the Kimmeridge Clay Formation; they accumulated on a clastic-dominated ramp subject to synsedimentary faulting as a result of the Atlantic Ocean rifting. In the Gris-Nez Cape area, i.e., close to the northern border fault zone of the Jurassic basin, the Late Jurassic sequence contains small-dimensioned oyster patch reefs (<1 m) that are specifically observed at the base of an abrupt deepening trend in the depositional sequence induced by well-defined pulses of normal fault activity. Petrographic analysis of these patch reefs shows that they are exclusively composed of *Nanogyra nana* embedded in a micro-sparitic calcite matrix. ™^{13}C measurements, carried out within both the matrix and the shells, display significantly lower values in the matrix compared to the oyster shells which suggests that the carbonate matrix precipitation was involving a carbon source different from marine dissolved inorganic carbon, most probably related to sulfate reduction, which is evidenced by light ™^{34}S in pyrites. Similarities but also differences with lucinid-rich bioconstructions, namely, the Late Jurassic pseudo-bioherms of Beauvoisin (SE-France) suggest that the patch reefs developed at hydrocarbon seeps are related to synsedimentary faults. The extensional block-faulting segmentation of the northern margin of the Boulonnais Basin in Late Jurassic times is thus believed to have induced a sort of small-dimension hydrocarbon seepage field, recorded by the patch reef distribution.

1. Introduction

Fluid flow is a first-order feature of basin evolution. Expulsing fluids are interacting with sediments at the earliest stages of deposition, causing both early and late diagenesis of sediments. This is particularly crucial for basins subjected to extensional tectonic activity, where synsedimentary faults drive early diagenetic fluid circulations. 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. 1). They represent a proximal equivalent of the Kimmeridge Clay Formation (famous as a 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 favorable to organic-rich deposition (Wignall, 1991; Ramanampisoa et al., 1992; Proust et al., 1995; Al-Ramadan et al., 2005; Deconinck et al., 1996; Wignall and Newton, 2001; Williams et al., 2001; Tribovillard et al., 2001, 2004, 2005). The Boulonnais is an excellent example of a small-dimensioned model of petroleum systems involving: 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 reservoir rocks. A recent study of the Bancs Jumeaux Formation suggested that synsedimentary tectonics induced fluid circulations through this incipient petroleum system, favoring carbonate precipitation and the formation of indurated carbonate beds, most likely stimulated by bacterial activity (Tribovillard et al., 2012).

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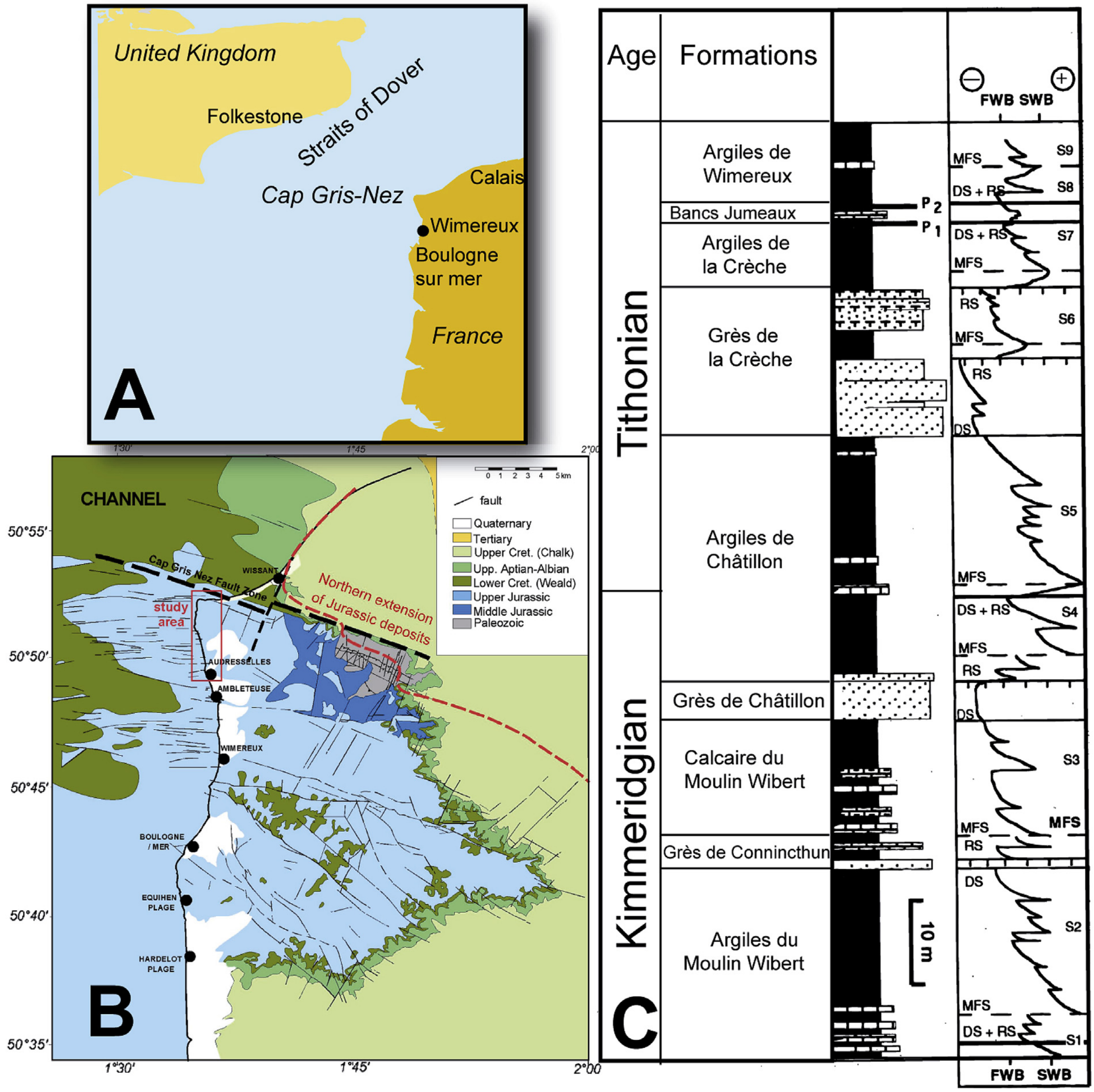

Figure 1. A – Large scale map showing the location of the study area, between the Gris-Nez Cape and the city of Wimereux. B – Geological map of the Boulonnais area (after Mansy et al., 2003). C – Simplified lithostratigraphic log of the Late Jurassic formations cropping alongshore the Boulonnais, showing the sequence stratigraphy framework (after Deconinck et al., 1996). FWB and SWB stand for fair-weather wave base and storm-weather wave base, respectively. P1 and P2 stand for the two horizons rich in phosphatized shells and pebbles.

From 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 course of the entire 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). This block-faulting geometry had a significant imprint on the subsidence pattern in the basin and, hence, on the depositional contexts. Along the Boulonnais cliffs, this resulted in significant lateral changes of sedimentary thickness and facies of the Kimmeridgian–Tithonian sequence indicating increasingly more proximal conditions toward the North, up to the Gris-Nez Cape fault zone that represents the present northern onshore extension of the Jurassic deposits (Fig. 1B) (Mansy et al., 2003). One of the main expressions of these lateral depositional variations toward the Gris-Nez Cape fault zone is a progressive increase in the number and thickness of coquina beds into the dominant mudstone–sandstone sequence (Fig. 1C; a coquina is a detrital limestone composed wholly or chiefly of mechanically sorted shell fragments that experienced abrasion and transport before reaching the depositional site; cf., Bates and Jackson, 1987). Actually, in the Gris-Nez Cape area, the Late Jurassic formations contain numerous coquina beds, exclusively composed of the oyster *Nanogyra nana* and representing proximal tempestite deposits (Mansy et al., 2007). Recently, in addition to the coquina beds, occasional, ball- or dome-shaped assemblages of *N.*