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Development and compartmentalization of chalky carbonate reservoirs: The Urgonian Jura-Bas Dauphiné platform model (Génissiat, southeastern France)

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Abstract

The chalky limestones of the upper Barremian-middle Aptian Urgonian Limestone Formation of the Jura-Bas Dauphiné platform (southeastern France) are characterised by a total porosity between 17.9 and 24.5%, a threshold radius between 1.04 and 2.13 μm, a trapped porosity between 51.4 and 68.3% and a gas permeability between 161 and 410 mD. They were formed in response to the diagenetic evolution of dominantly micritic sediments deposited during a "calcite sea" interval. Their present-day reservoir qualities and transport properties are controlled by the intercrystalline microporosity of microcrystalline areas (peloids or matrix). This intercrystalline microporosity is the product of a meteoric porewater input (installation of a shallow-burial phreatic environment characterised by a short residence time of porewaters) which promoted an aggrading neomorphism (Ostwald ripening process). The impact of the burial diagenesis on the reservoir qualities and the transport properties of these chalky limestones is limited.

The chalky units are presently compartmentalized by horizontal layers of compact limestones characterised by a total porosity between 2.9 and 4.5%, a threshold radius between 0.04 and 0.09 μm, a trapped porosity of 92.4–92.8% and a gas permeability of 2 mD. Like the chalky limestones, the present-day reservoir qualities and transport properties of compact limestones are controlled by the intercrystalline microporosity of microcrystalline areas. The petrophysical differences between the chalky and compact limestones result from differences in the pore network of microcrystalline areas due to an increase in the average size of particles and a modification of crystal–crystal contacts. These petrographical differences reflect an evolution of micritic areas of original sediments during submarine lithifications (precipitation of microcrystalline cements within the pore space and/or an increase in solid–solid contacts by crystal growth) which preceded the aggrading neomorphism induced by the meteoric porewater input.

Keywords: Carbonate reservoir; Diagenesis; Micrite; Microporosity; Cretaceous; Platform

1. Introduction

Numerous major petroleum reservoirs come from chalky carbonates. The chalky textures are due to microporous networks existing within microcrystalline areas (matrix or grains) of dominantly fine-grained

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platform carbonates. Many hypotheses for the development of chalky textures have been proposed (Handford et al., 1989; Munnecke et al., 1997; Lambert et al., 2006) but the divergence of ideas clearly shows that additional works are needed.

The Urgonian Jura-Bas Dauphiné platform in southeastern France is an international reference for the study of carbonate platforms. It notably permitted the testing of sequence-stratigraphic principles (Arnaud-Vanneau and Arnaud, 1990; Jacquin et al., 1991; Hunt and Tucker, 1993a,b; Everts and Reijmer, 1995; Everts et al., 1995). Several studies were devoted to the diagenesis of the Urgonian Jura-Bas Dauphiné platform carbonates (Arnaud-Vanneau and Carrio-Schaffhauser, 1994; Fouke et al., 1995; Moss and Tucker, 1995; Fouke et al., 1996; Moss and Tucker, 1996; Carrio-Schaffhauser et al., 2001; Fouke et al., 2005) but none focussed on the chalky limestones of the upper Barremian-middle Aptian Urgonian Limestone Formation.

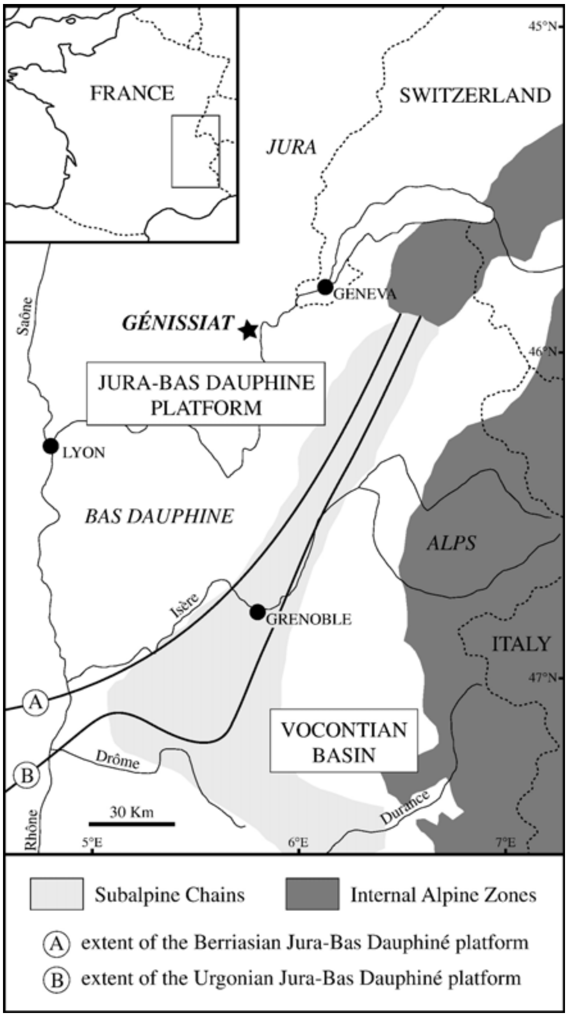

Fig. 1. Map showing the location of the Génissiat quarry and the contrast in extent of Berrisian and Urgonian Jura-Bas Dauphiné platforms (palaeogeographical data from Hunt and Tucker, 1993a).

The aim of this paper is (1) to describe in detail the present-day petrophysical signature of the chalky limestones of the Urgonian Jura-Bas Dauphiné platform, (2) to clarify their development (timing, environment, diagenetic processes and evolution of the pore network) and (3) to make clear their compartmentalization by compact limestones. To achieve these objectives, we combined petrographic observations with geochemical data and petrophysical measurements.

2. Geological setting and sampling

The Urgonian Jura-Bas Dauphiné platform crops out in the French Jura and the Subalpine Chains (Fig. 1). It is the latest platform which developed on the Jurassic–Cretaceous passive continental margin of the Ligurian Tethys (Lemoine et al., 1986; Hunt and Tucker, 1993a). The extensional deformation along this margin was accommodated by large displacements along major lineaments trending NE–SW or NW–SE. One of NE–SW lineaments, the Isère fault, separated two distinct palaeogeographic domains (Arnaud-Vanneau and Arnaud, 1990): the Jura-Bas Dauphiné platform to the northwest and the Vocontian basin to the southeast (Fig. 1). The Jura-Bas Dauphiné platform is dominated by shallow-water platform facies and the Vocontian basin contains down-dip equivalent basinal and periplatform facies. The Urgonian Jura-Bas Dauphiné platform can be divided into two parts: (1) the lower Barremian Borne Formation and the lower-upper Barremian Glandasse Bioclastic Limestones Formation and (2) the upper Barremian-middle Aptian Urgonian Limestone Formation with inner platform rudistid facies (Arnaud-Vanneau and Arnaud, 1990; Hunt and Tucker, 1993a). During the Urgonian, the Jura-Bas Dauphiné platform evolved from an open, locally rimmed shelf, to an aggraded shelf and, lastly, a rimmed shelf (Hunt and Tucker, 1993b).

Eighteen samples (G1 to G18) were collected along a working face (Fig. 2) in the Génissiat quarry where the upper Barremian-middle Aptian Urgonian Limestone Formation crops out. This quarry is located in eastern France, between Lyon and Geneva, at two kilometers to the northwest of Génissiat town (Fig. 1). The studied section is 7.95 m high (Fig. 2). It consists of inner platform rudistid facies. It shows a vertical alternation between chalky and compact limestones (Fig. 2): the compact limestones form two low-porosity (3 to 4.5%) horizontal layers which compartmentalize a high-