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Depositional Facies and Sequence Stratigraphy of Reservoir Nummulite Bodies in Central Tunisia (El Garia Formation, Upper Ypresian). Results of a Field Analogue Study from the Kesra Plateau

Abstract

Eocene nummulite deposits of the southern Tethys margin constitute important hydrocarbon fields. This paper describes the Late Ypresian nummulite deposits from the Kesra Plateau in Central Tunisia. In Kesra, the well-exposed outcrops led to define a precise lithostratigraphic interval according to the determination of nummulites and planktonic foraminifera. Deposits of the El Garia Formation directly overlay the Cretaceous limestone of the Abiod Formation. The unconformity between both formations corresponds to a 14 Ma of sedimentary hiatus and the duration of the deposition of the El Garia Formation is estimated about 2 Ma.

Eight depositional facies have been identified in respect with the petrographic texture, the faunistic assemblage and the sedimentary structures. Nummulite morphological variability allows to distinguish four types of nummulite deposits, which reflect different depositional environments. High-energy nummulite facies are characterised by local sub-aerial exposures.

The 3D reconstruction of sedimentary bodies led to identify two isolated nummulite bodies. The thicker accumulation of nummulite facies corresponds to the stacking of successive periods of high-energy settings. Laterally, these stacked nummulite bodies evolve in two main disconnected bodies towards the eastern part of the Plateau, where they are interfingered with microporous nummulithoclastic limestones.

It is demonstrated that the configuration of the nummulite platform is strongly influenced by the pre-structuration of the area in horst and graben structures. A 3D facies model is proposed to illustrate the relation between facies and fault distributions observed in the Kesra area. It differs from a homoclinal ramp model, which suggests that nummulitic facies are deposited along a progressive gentle slope on the mid-ramp, under 20 to 60 m water depth. At Kesra, good potential reservoirs are generated by storm events under few meters water depth.

Introduction

Along the southern Tethys margin, a Lower Eocene nummulite platform covered the area between Central Tunisia and the Gulf of Gabès (Bishop, 1988; Zaïer *et al.*, 1998).

In order to improve prediction of stratigraphic architecture and internal heterogeneity of the libyan offshore area (C137 licence operated by TotalFinaElf), a thorough examination and interpretation of the nummulitic series outcropping at the Kesra Plateau in Central Tunisia have been carried out (Jorry *et al.*, 2001; Jorry *et al.*, in press). This area is particularly suitable for such a study as continuous well-exposed outcrops allow detailed mapping of nummulite facies, delineation of nummulite bodies and therefore understanding of vertical and lateral facies distribution on a sub-surface reservoir scale (6 km * 8 km).

Geological settings

In Kesra, five main Formations are recognised at outcrop (Fig.1): the Campanian Aleg Formation deposits, the lime mudstone of the Maastrichtian Abiod Formation, the Late Ypresian nodular Chouabine Formation, the El Garia

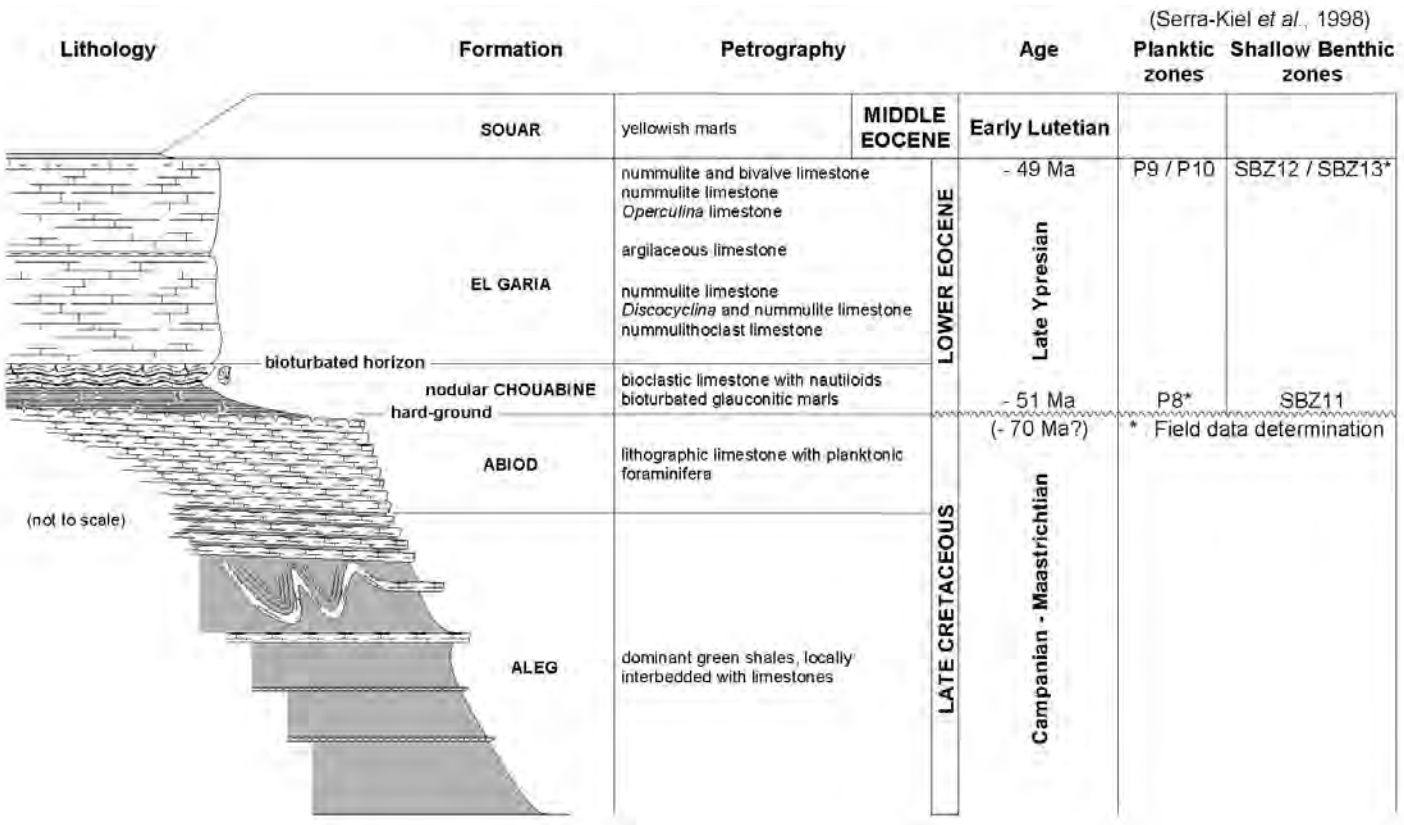

Figure 1.
Lithostratigraphy and simplified sedimentological succession of the Kesra Plateau

Formation (the nummulitic unit) in which is intercalated the nummulithoclastic facies of the Ousselat member, and the yellowish marls interbedded with massive oyster accumulations belonging to the Lutetian Souar Formation.

Based on outcrop observations, on the description of 24 field sections, and the petrographic study of 420 thin sections, six principal facies within the El Garia Formation have been distinguished: Large robust nummulite packstone, Small robust nummulite grainstone / packstone, Large flat nummulite grainstone / packstone, Small flat nummulite packstone, *Operculina* and nummulithoclastic packstone, Nummulithoclastic packstone.

Construction of a facies model

In order to establish a facies model for the El Garia Formation outcropping in Kesra, we used a method proposed by Walker (1984) and derived from Walther's law (Walther, 1894; Middleton, 1973) and based on the most frequent stratigraphic facies transitions. Applying this method to the standard facies recognised in the Kesra Plateau, we devised a theoretic shallowing-up sequence, from the deeper nummulithoclastic packstones up the shallower small robust nummulite grainstones.

It is clear that nummulithoclast silt-sized deposits are clearly produced by the reworking of nummulite-rich facies from proximal zones, but processes of fragmentation remain enigmatic. The distribution of nummulite facies is controlled by environmental processes (salinity, temperature, light intensity), biological processes (reproductive strategy, bioturbation) and hydrodynamic conditions. Thus, large flat nummulites in which intra-skeletal porosity may reach up to 40 % can easily be transported (Aigner, 1985 and Racey, 2001). At Kesra, metric cross-bedding structures of imbricated nummulite grainstones suggest a reworking of the nummulite-rich sediment by currents.

3D visualisation of the correlated profiles

The 3D reconstruction of sedimentary bodies was based on the integration of data from logged stratigraphic sections, 2D outcrops subsequent and 3D modelling. In term of reservoir potential, two isolated nummulite bodies are particularly well identified. These two reservoir bodies are stacked at the south-western part of the studied area, which indicates that this area corresponds to a suitable environment for nummulite-rich facies deposition, where high-energy conditions prevail. In this case, the succession of storm events has contributed to the deposition of the thicker nummulite shell accumulation. Laterally, these stacked nummulite bodies evolve in two main disconnected bodies towards the eastern part of the Plateau, where they are interfingered with microporous nummulithoclastic limestones.

3D facies model

The synthetic facies model presented in Figure 2 takes into account detailed facies and fault distributions observed in the Kesra Plateau area. The establishment of palaeogeographic maps indicated that the facies belts are more or less parallel to the NW-SE faults. The main nummulite carbonate production rests on the Cretaceous paleo-high, with the deposition of small robust nummulite facies at its top. This facies, which occasionally shows the association with serpulids bioherms, evidence conditions of local sub-aerial exposures. Nummulite bars with high concentrations of large, flat, imbricated nummulites in cross-bedding structures, formed under the action of currents in shallow water depth. Behind these bars were protected zones in which large robust nummulites and large bivalve packstones were deposited. In front of the nummulite bars, small nummulite and *Discocyclina* packstones are present and characterise a more open-marine environment.

Main potential reservoirs are located on the top of paleo-highs, where a prolific environment for nummulite facies deposition took place. At Kesra, the important accumulation of nummulithoclast-dominated facies within the narrow intra-shelf basin constitutes an equivalent as a tight reservoir. However, the presence of organic matter suggests that these deposits could constitute a potential source rock close to the nummulitic reservoir.

Conclusions

Detailed petrographic and stratigraphic descriptions of Lower Eocene series from the Kesra Plateau show that the El Garia Formation is characterised by frequent facies and thickness variations, from the SW nummulitic facies to the NE thick nummulithoclastic accumulations.

A 3D modelling of the correlated profiles allows to detail the internal architecture of a nummulite reservoir body. It is demonstrated that sequences of reservoir nummulite rocks deposition are stacked in proximal areas, while they constitute two disconnected bodies towards the distal part of the platform.

Extended observations at a regional scale led to precise the configuration of the Late Ypresian platform was strongly influenced by the presence of the Oued Bahloul anticline structure, which formed a major environmental barrier between an open-marine and a more protected settings. At Kesra, facies transitions are controlled by residual topography resulting from reactivation of NW-SE faults during the Late Cretaceous and the Palaeocene.

A 3D facies model is proposed to illustrate the relation between facies and fault distributions observed in the Kesra area. It differs from a homoclinal ramp model, which suggests that nummulitic facies are deposited along a progressive gentle slope on the mid-ramp, under 20 to 60 m water depth. At Kesra, good potential reservoirs are generated by storm events under few meters water depth.

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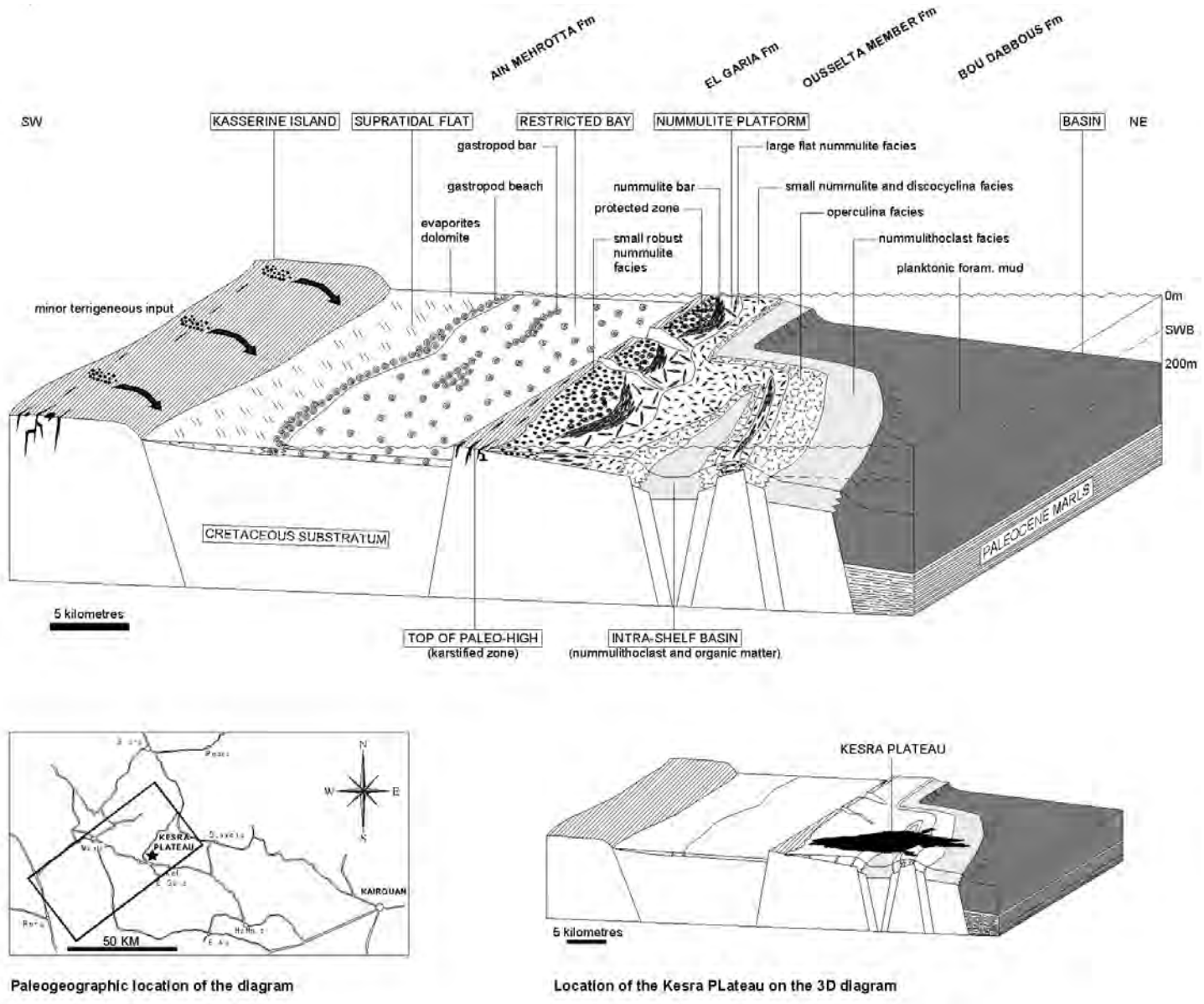

Figure 2.
3D facies model showing the distribution of the Upper Ypresian carbonate deposits in Kesra area (Central Tunisia)

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