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Carbonate platform-margins and reefs distribution using 2-D seismic analysis, Central Tunisia

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ABSTRACT

The seismic characterization of sedimentary facies in a carbonate platform, comprising different types of reefs constructions, is based using two-dimensional (2-D) seismic and borehole data. Reefs of the Aptian Serdj carbonates are shown as mounds of strong chaotic amplitudes that have a high-amplitude continuous reflection at the top. They are sealed by Albian marl and claystone deposits characterized by mid- to low-amplitude, parallel and discontinuous to weak reflections. These buildups were restricted to the outer platform margin of Central Tunisia. Sea level oscillations associated with master fault rejuvenation governed the growth, the distribution and development of these reefs. Their distribution is largely controlled by deep-seated fault-related folds and the topography of underlying structures, representing local domal uplifts. Falls of sea level led to subaerial exposure and the development of a karstified denudation of the carbonate platform. Subsequently, reefs were partially or totally destroyed and then overlain, during the Albian, by marls and claystones of the Fahdene Formation. Their study indicates that reef buildups have important oil and gas exploration potential, not only onshore, but also in offshore, Central Tunisia.

1. Introduction

During the Lower Cretaceous, carbonate sediments were widely deposited in the southern Tethyan margin, including the Central Tunisian Atlas. This area corresponded to a shallow-water environment where spatially extensive accumulations of carbonate platforms were developed. The architecture and evolution of such platforms are governed by several complex factors including tectonics and sea level oscillations. Previous studies of the development of reef complexes are well documented in Tunisian academic and industrial literature, both in outcrop studies and subsurface: the late Permian reef facies in the Jeffara basin (Ben Ferjani et al., 2006; Bouaziz et al., 2002; Newell et al., 1976), the Campanian rudistic reef-buildups of Central Tunisia (Negra, 1994), the Tithonian remnants of a shallow carbonate platform in the eastern part of the Tunisian Atlas (Ourribane et al., 2000), the Messinian coral complex in the eastern platform (Gaaloul and Razgallah-Gargouri, 2008), Coniacian rudist-buildups recognized in the Dernaia-Tamesmida area (west Central Tunisia) (Saidi et al., 1997) and the Cenomanian reef limestones discovered in the Isis oil field on the eastern offshore plateau (Bishop, 1975; Gargouri-Razgallah, 1983; Marie et al., 1982).

Numerous studies about the existence of Aptian reefs recorded along the Tethyan margin and also elsewhere. Indeed, sediments including reefal buildups in the Sligo Formation (Early Aptian) are clearly described by Kirkland et al. (1987) and Mathis (1982), and are also identified as hydrocarbon reservoirs along the United States Gulf Coast. Over the eastern Arabia and eastern Persian Gulf, the Aptian Shuaiba Formation consists of a large rudist reef buildup with calcareous algae and orbitolinids which extends in a subcircular pattern (Edgell, 1997). These series correspond to limestone reservoirs of the United Arab Emirates, and includes the oil fields of Sirri (offshore Iran), Idd al Shargi (offshore Qatar), Safah (Oman), Shah (Abu Dhabi) and the giant Shaybah-Zarrara Field (Saudi Arabia). Westwards, in Slovenia, reef buildups colonized the rim of the Dinaric platform (Kirmaci et al., 1996) and ascribed as a series of patch reefs (Middle-Aptian), towards the Sabotin Mountain, across the West of Slovenia (Koch et al., 2002). In Spain, dolomitized reefs are documented in sediments of Late Aptian age and closely relate to stratiform ore deposits (Monseur and Pel, 1972). The reef limestones of the Aptian Serdj reservoir (Zouaghi et al., 2011, Zouaghi, 2008; Troudi, 2007; Ben Ferjani et al., 2006; Ouahchi et al., 1998, 2003; M'Rabet, 1981) constitute a very widespread type of depositional system and contain significant volumes of hydrocarbons in onshore and offshore Central Tunisia. Onshore

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Central Tunisia has been subjected to petroleum exploration research since 1963, when several oil fields were discovered in the Douleb/ Semmama and Tamesmida area. Some of the prominent studies reveal that Aptian reservoirs have attracted considerable attention for its hydrocarbon prospectivity, especially for oil (Zouaghi et al., 2009; Zouaghi, 2008; Ben Ferjani et al., 2006; Ouahchi et al., 1998, 2003; Bishop, 1975). Thus, limestones of the Aptian Serdj Formation are found to contain significant commercial accumulations of oil and gas and ore deposits (galena and barite), mainly in the uppermost part of the Formation.

The imaging of carbonates is still a challenge for seismic interpretation, since the imaging of reef patterns are more complex. The success in imaging reefs and small and isolated reefal limestones or, so called, patch reefs or pinnacles reefs that are intercalated in carbonate strata makes the Central Tunisia a key area to study the controlling factors of Aptian shallow-water facies development. The detailed seismic reflection patterns for reef geometry are difficult to identify which is explained by the high density of fractures combined with the impact of halokinetic activity. Seismic identification of reefal buildups is deduced from the depositional sequence identified from well data and the regional Aptian tectono-sedimentary architecture. Essential for exploration drilling, is the identification of high porosity and fractured beds within the reservoir for the choice of well location. More than 30 wells have been drilled and thousands of kilometers of 2-D seismic data have been acquired to ensure that Central Tunisia has a promising future for oil and gas exploration and production. The Entreprise Tunisienne des Activités Pétroliéres (ETAP) and other companies (SEREPT, etc.) have performed the majority of exploration activities. The results obtained from the wells drilled and the interpretation of seismic profiles allows geoscientists to obtain new information concerning subsurface geology within the study area. This paper aims to define the stratigraphy and the seismic characteristics of carbonate facies and reefal buildups, based on depositional sequences deduced from well data and Aptian sequence stratigraphy, to recognize the controlling factors of the development of this construction and finally to identify favorable carbonate rock provinces as potential reservoirs.

2. Geological settings

During the Early Cretaceous, the Central Tunisian Atlas was located on the southern Tethyan margin. The study area consists of tectonic depressions and uplifts that developed during the Late Cretaceous collision between the African and Eurasian plates (Martinez et al., 1991; Dercourt et al., 1985). Structurally, the study area includes several NE–SW salt cored anticlines at Lower Cretaceous level (Zouaghi et al., 2011, Zouaghi, 2008; Azaïez et al., 2007; Tanfous-Amri et al., 2005; Bédir, 1995) and development of synsedimentary normal faults. To the east of these structures lies a large stable area, the Pelagian platform (Fig. 1). The former is separated from the Atlas of Tunisia by a major north–south-oriented mountain chain that was developed along an important early sub-meridian-trending fault during the Alpine orogeny, the North–South Axis (Abbès, 2004; Rabhi, 1999; Piqué et al., 1998; Creuzot and Ouali, 1989). During Lower Cretaceous, sea level changes and syn-sedimenatry normal fault movement, coeval with halokinesis activity, controlled the tectono-sedimentary architec-

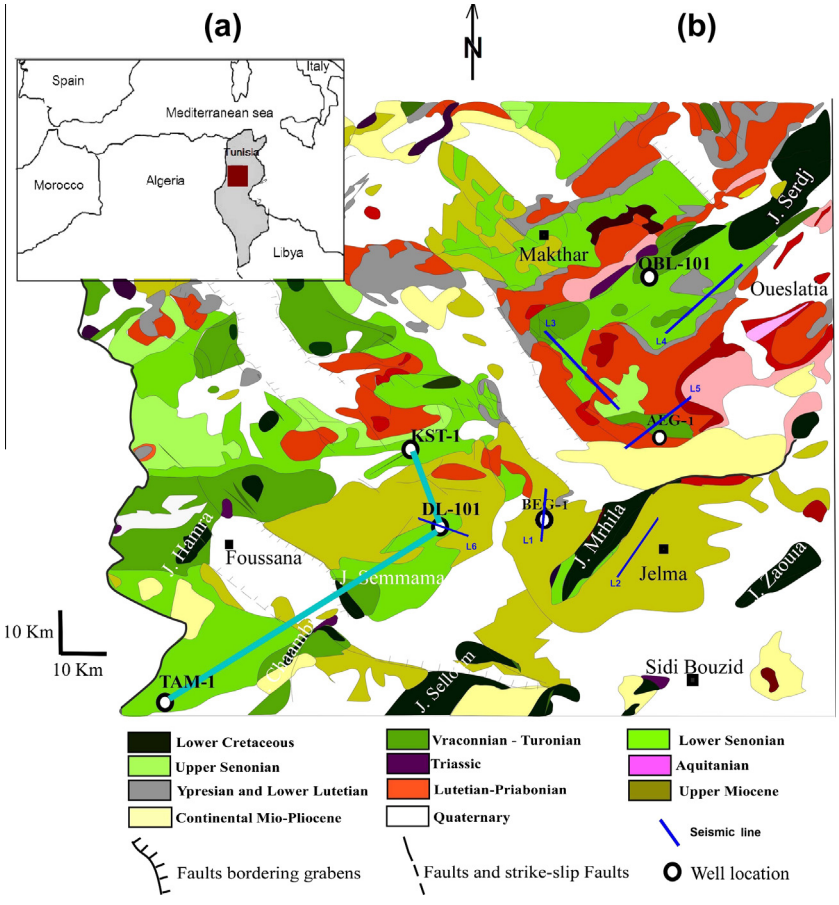

Fig. 1. Location of the study area in the Central Tunisia; (a) the inset gives its position within Mediterranean Sea. (b) Simplified geological map of Central Tunisia showing the main geological units, according to Ben Hadj Ali et al. (1985). The study area is formed by NE–SW and E–W transverse anticlines with Lower Cretaceous heart separated by vast synclines generally filled by Mio-Pliocene deposits. Location of seismic lines and wells is shown in the study area.