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Vertical Movements and Petroleum System Modelling in the Southern Chotts Basin, Central Tunisia

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Abstract

The southern Chotts basin (SCB), Central Tunisia, has shown hydrocarbon potential since the end of the 1980s. This basin records a complex structural history which appears decoupled at the Hercynian or Variscan unconformity. The Paleozoic series is deformed by short to medium wavelength folds (kilometres-multi kilometres scale) and by steep normal faults. The Mesozoic series is largely less deformed. The evolution of the basin through time is still a matter of debate as the preserved Paleozoic series is fragmented (e.g. affected by erosions). In this paper, we proposed a reconstruction of the vertical movements affecting the basin and an evaluation of their magnitude. Using basin modelling techniques, we provided new insights on the possible thermal evolution of the basin that might be used in the future exploration phases. This study was completed by structural restorations allowing the reconstruction of the paleogeography of the basin at the time of deposition of principal reservoir formations.

Keywords

Southern Chotts basin • Vertical movements • Basin modelling • Structural restoration • Fractures

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1 Introduction

The southern Chotts basin (SCB) is located in Central Tunisia, about 140 km southwest of the Gulf of Gabes. This area is a proven prolific oil and gas province since the early 1980s. In this area, the most important and productive reservoirs are located in the Ordovician mixed sandstone and siltstones of the El Atchane and of the Hamra formations and in the Triassic sandstone of the TAGI unit (Trias Argilo-Gréseux Inférieur), (Mejri et al. 2006). The principal source rock feeding these reservoirs is the Late Silurian to Early Devonian shale and siltstone of the Fegaguira Formation (Soua 2014). The Fegaguira shales also acts as a caprock for the Ordovician reservoir system. For the TAGI, the overlying Triassic anhydrites and salt are considered as the main reservoir caprock. The nature of the traps in the Ordovician is mainly of structural origin (system of horst and graben), whereas traps are more of stratigraphic origin for the TAGI (fluvial staked systems).

2 Geological Setting

Between the Cambrian and the Cretaceous, the SCB underwent a complex and polyphased tectonic history resulting in contrasted basin architecture before and after the so-called Variscan unconformity. Seismic data in the Pre-Variscan package showed folding of various wavelengths and a variable faulting intensity within the SCB. Between the Cambrian and the Permian, extensional tectonics and large scale inversions took place and resulted, respectively, in: the onset of an arch and basin configuration (Lüning et al. 2005) and (ii) major uplift phases marked by successive internal erosion within the Paleozoic series. The Post-Variscan package is quieter and displays a layer-cake configuration. Between the Jurassic and the Early Cretaceous a long phase of continuous subsidence occurred.

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3 Results

3.1 1D Subsidence and Basin Analysis

The present study focused on the evaluation of the timing and magnitudes of vertical movements affecting the SCB. A series of subsidence curves (based on an extensive literature synthesis and on seismic observations) was created based on 14 petroleum wells. The comparison of the subsidence curves (Fig. 1) showed a relatively stable subsidence history throughout the basin but a variable magnitude of the vertical movements from one well to another.

In addition, a 1D basin modelling was performed based on 6 of the 14 selected wells. This modelling used the geological history obtained from the subsidence curves. To complete these data, the geochemical properties of the principal source rocks were gathered from literature and from sampling and analyses available from the wells. The sediments-water interface conditions were obtained from Wygrala (1989) algorithms. The present-day heat flow was calibrated using the corrected bottom hole temperature, and multiple scenarios were proposed for the paleo heat (calibrated using vitrinite reflectance dataset). The results of our models allowed separating two groups of wells: (i) in wells 3, 8 and 9, the oil window is attained at the end of the Jurassic and (ii) in wells 5, 6 and 7, the oil window is entered at the beginning of the Devonian (to be related with the onset of the Caledonian uplift). Based on these results, we found that the Fegaguira formation is mature and started to produce hydrocarbon earlier than the Devonian and at least during the Jurassic. The migration occurred after these periods and probably at the beginning of the Paleocene (Kraouia et al. 2019).

3.2 2D Restoration

Sequential structural restorations based on 16 regional seismic transects permitted evaluating the structural style of the deformation observed in the area of interest and evaluated the initial amount of TAGI and Early Ordovician sediments deposited in the basin. Whilst compared with the present-day depth maps of the TAGI and Ordovician reservoir, the paleo-topographic maps revealed local vertical movements of the basin (Fig. 2).

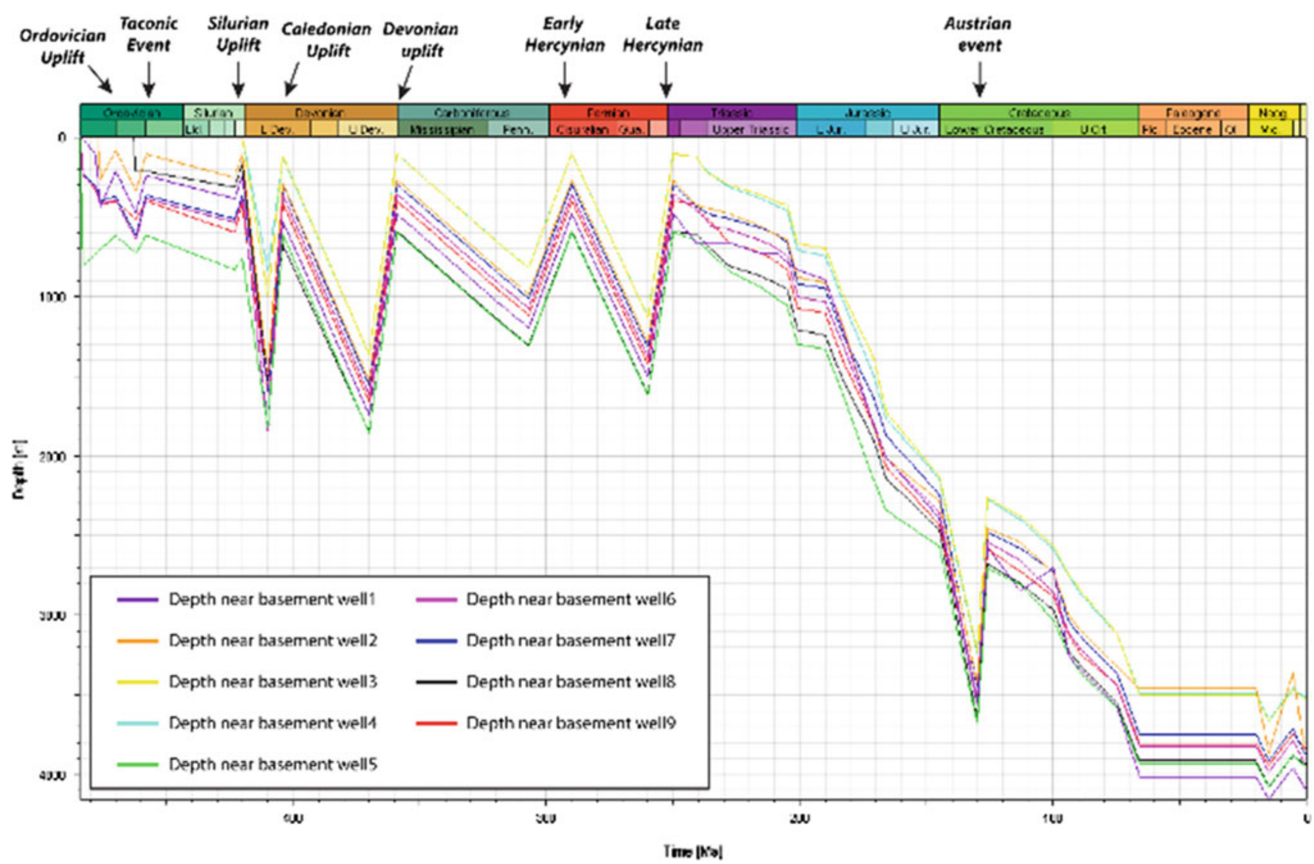

Fig. 1 Compared burial curves in wells located in the western part of the southern Chotts basin

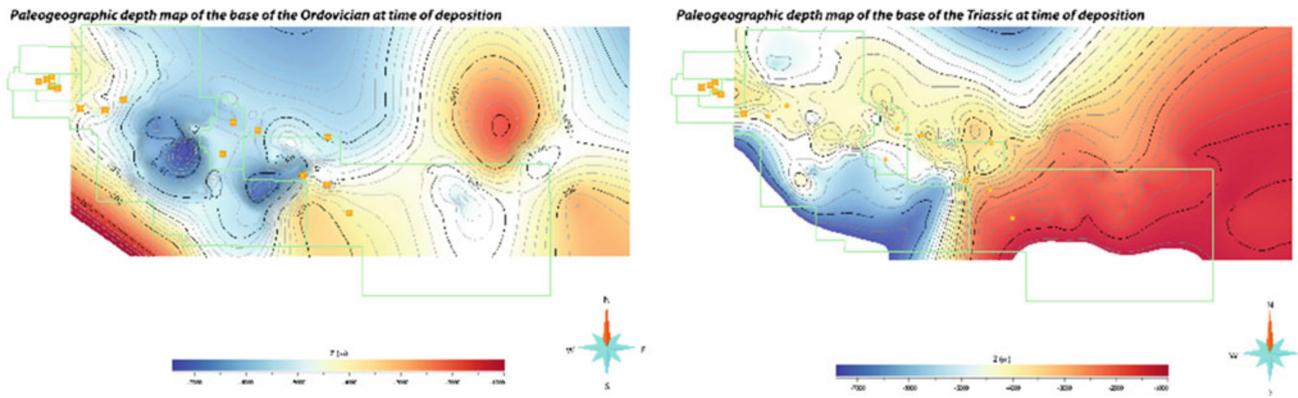

Fig. 2 Base of the Ordovician (left-hand side) and of the Triassic packages (right-hand side)

4 Discussion and Perspectives

The reconstructed subsidence history allowed proposing a possible renewed scenario of the vertical movements affecting the area of interest especially during the Paleozoic. Uncertainties about the burial history remain related to the timing of deposition and erosion phases. This has potential implications for petroleum system maturity and therefore for future exploration planning. A campaign of sampling for apatite fission track analyses (AFTA) conducted in selected wells and outcrops of the Jeffara escarpment are planned to be conducted in the coming months. These thermo-chronological data will greatly help to validate or adjust our structural history and to link it with the thermal maturation of the hydrocarbon systems in the SCB.

The sequential restoration allowed building paleogeographic maps showing the geometry of the basin at the time of deposition of the Ordovician and Triassic packages. The present-day base of the Ordovician show a high topography in the southern part of the model. The paleogeography of the Triassic highlighted the presence of a high (anticline) parallel to the Telemzane Arch and separated from it by a relative low (syncline?). This geometry has a strong implication for sand filling and provenance and will allow reducing the number of hypotheses concerning the dynamic of the sedimentary system in this area. For the future, 2D basin modelling (using PetroMod software) could be performed to evaluate the migration path within the basin and eventually evaluate where sweets spots can be located.

The perspective of this study is focused on natural fractures characterisation and on the establishment of the link between the large scale vertical movements and the small scale deformations. The Ghrib block, located in the western part of the area of interest, was chosen as a pilot to build discrete fracture network models of the Early Ordovician and Triassic reservoirs. The paleo-topographic reconstruction demonstrated that the area was located on the limb of an arch structure (during the Ordovician) and in a synclinal structure (during the Triassic). Consequently, these zones might be affected by different fracture types which can be related to variable strain conditions. During the same AFTA campaign, fracture analysis (geometrical characterisation, dating) will be performed in outcrops presenting similar configurations to evaluate the possible analogy between the Jeffara escarpment and the subsurface.

5 Conclusions

In this study, a combination of 1D basin modelling and 2D structural restorations was used to get new insights on the petroleum system history of the SCB. The 1D basin modelling served to test different scenarios of tectonic history and evaluate their impact on the thermal evolution of the SCB petroleum system. The restoration of the basin geometry was used to locate vertical movements' anomalies and evaluate the initial thicknesses of the Ordovician and Triassic reservoirs at the time of their deposition. Ongoing research aims to improve the preliminary results of this research on a large scale and to offer a better small scale structural characterisation in the SCB.

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