



Organic maturation of the Algarve Basin (southern Portugal) and its bearing on thermal history and hydrocarbon exploration



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ABSTRACT

The Algarve Basin, southern Portugal is under-explored in terms of petroleum geology. Organic maturation levels and the thermal history of this basin have been ascertained, together with their implications for future exploration. Maturity was determined using vitrinite reflectance and spore fluorescence/colour. The succession was extensively sampled (158 onshore samples and 20 samples from two offshore wells). Thermal history was modelled using 1D PetroMod[®].

A palynostratigraphic study of two offshore wells was also completed, showing thick marl–limestone sequences of Middle and Upper Jurassic age. Hiatuses were identified in the offshore wells within the Jurassic section and between the Jurassic and the Miocene sections.

The Mesozoic rocks of the Algarve Basin lie within the oil window. Vitrinite reflectance ranges from 0.52–0.7%*R_r* in the Lower Cretaceous to 1–1.1%*R_r* in the Upper Triassic–Hettangian. Miocene rocks that unconformably overlie the Mesozoic strata are immature (0.42–0.47%*R_r*). Maturation levels increase with increasing age of the strata, indicating that burial was the main process controlling maturation. Thick marl–limestone sequences of the Middle Jurassic (Callovian) and the Upper Jurassic (Oxfordian) are the main source rock intervals. The Miocene successions of both offshore wells contains reworked vitrinite and palynomorphs with maturation levels similar to the Mesozoic rocks of the basin, suggesting exposure and erosion of these rocks during Miocene times.

Palaeogeothermal gradients in the onshore Algarve Basin range from 52 °C/km to 24.7 °C/km with pre-Miocene exhumation estimated at 2000–2500 m. The probable age for the removed cover is Upper Cretaceous to Lower Palaeocene(?) and peak temperatures in the Mesozoic rocks were attained during latest Cretaceous–Early Palaeocene times. Modelled palaeotemperatures suggest that the Jurassic entered the oil-window at the beginning of the Cretaceous with peak oil generation in late Cretaceous time.

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1. Introduction

The Algarve Basin is a Mesozoic to Cenozoic sedimentary basin located in southern Portugal, cropping out along the entire south coast from Cape Saint Vincent in the west to the Guadiana river on the Portuguese–Spanish border in the east (Fig. 1). The basin extends offshore, where it has been recognized in seismic lines and 5 hydrocarbon exploration wells (Fig. 1). The Mesozoic geology of the

Algarve Basin is, therefore, better known onshore than offshore and comprises sedimentary rocks ranging in age from Upper Triassic to Lower Cretaceous, constituting a succession over 3 km thick in the depocentre of the basin in the central Algarve.

The development of the Algarve Basin is related to consecutive phases of rifting associated with the break-up of Pangaea. Its origin, location, sedimentary record and evolution during the Mesozoic are closely related to a series of basins that developed during the opening of the North and Central Atlantic Ocean, including, for example, the Lusitanian Basin in central Portugal, the Porcupine Basin in offshore western Ireland and the Scotian, Whale and Jeanne d'Arc basins in offshore eastern Canada (Wilson et al., 1989). Although the main geological features of the Algarve Basin have been summarised in several publications (e.g. Manuppella et al., 1988; Terrinha et al., 2013), none of these discuss organic maturation

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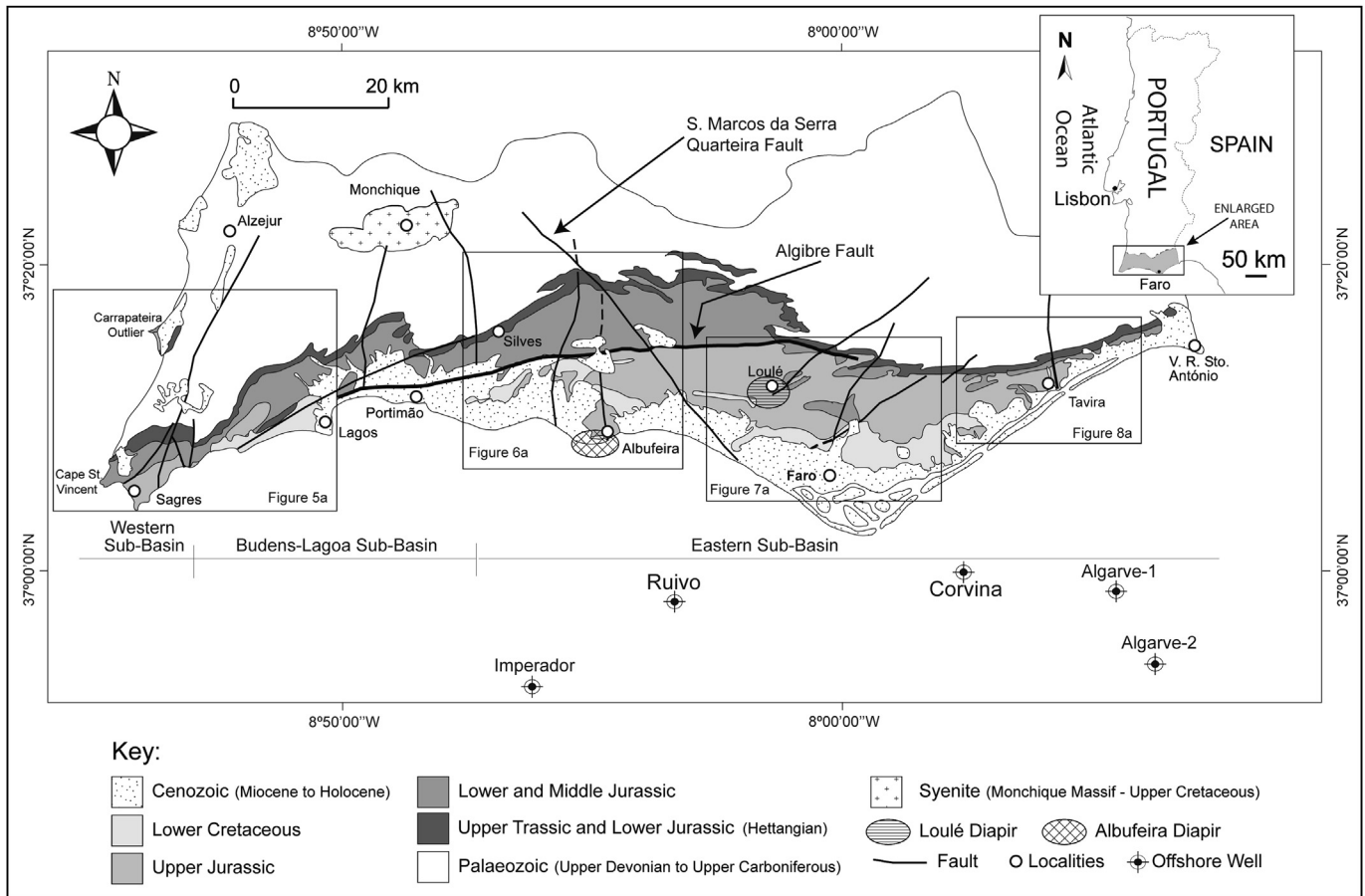


Figure 1. Generalized geology of the Algarve Basin showing the geographical extent of the Western, Budens–Lagoa and Eastern Sub-Basins, the offshore wells and the position of Figures 5a, 6a, 7a and 8a (adapted from Borges et al., 2011).

levels and thermal history, and their implications for the hydrocarbon exploration. Aspects of the petroleum geology are included in unpublished reports produced by oil companies that were active in exploration of the offshore basin between the late 1960s and early 1980s (Chevron, 1975; Challenger, 1976) and in an unpublished Ph.D. thesis (Matias, 2007). However, these summaries contain few data regarding the organic maturation levels of the Algarve Basin and mainly deal with the stratigraphy, micropalaeontology and modelling of exploration wells drilled in the offshore. The few maturation data in these reports are mostly limited to spore colour determinations. In this work, we present vitrinite reflectance (VR) results from 178 rock samples and use these data to estimate their thermal maturity, model the thermal history of the Algarve Basin, and discuss implications for hydrocarbon exploration, especially in the offshore part of the basin.

Thermal history analysis is an indispensable part of any study of sedimentary basins and their hydrocarbon source potential. There are several methods, both optical and geochemical, which can be used to ascertain the temperatures attained by strata during subsidence and interpret their thermal history. VR is an optical method considered a reliable indicator of the organic maturation levels of sedimentary rocks (Hunt, 1996; Robert, 1988; Tissot and Welte, 1978; Bordenave et al. 1993). Since organic maturation levels are largely related to temperature, VR is also a good indicator of peak (palaeo)temperatures, which accounts for its widespread use in basin analysis and hydrocarbon exploration.

Good age control of the sedimentary successions is also fundamental in basin analysis studies related to hydrocarbon exploration

and exploitation. This is even more significant in areas where the subsurface geology is mainly recognized by seismic lines (Esso, 1982a,b; Challenger, 1976; Chevron, 1975) and only by five exploration wells, as is the offshore part of the Algarve Basin (Fig. 1). Micropalaeontology and palynology are the staple palaeontological techniques used to determine the age and biostratigraphy in wells and boreholes. In this study, in order to calibrate the ages of offshore geological units of the Algarve Basin and allow correlation with the onshore geology, two wells, Rujivo and Corvina (Fig. 1), were studied for palynology.

2. Geological background of the Algarve Basin

2.1. Onshore geology

Sedimentation in the Algarve Basin was initiated in Late Triassic times with the deposition of continental red beds and evaporites, which unconformably overlie folded and faulted Carboniferous strata (Palain, 1976) (Fig. 2). The red bed succession (Silves Sandstones) consists of sandstones and conglomerates at the base, overlain by variegated mudstones interbedded with siltstones and dolomites (Silves Mudstones – Siltstones and Dolomites). The sandstones were deposited in alluvial environments and the mudstones in alluvial to shallow lacustrine environments. At the top of this sequence, to the south of the E–W trending Algre Fault (Fig. 1), there are thick evaporitic deposits, whereas north of this major structure, the evaporites are virtually absent. The evaporites mark the first marine incursions into the basin and yield Early

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