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Meso-/Cenozoic long-term landscape evolution at the southern Moroccan passive continental margin, Tarfaya Basin, recorded by low-temperature thermochronology

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ABSTRACT

This paper presents the first regional study of low-temperature thermochronology to be undertaken in the Tarfaya Basin at the southern Moroccan passive continental margin. The basin is characterised by vast subsidence since Mid-Triassic times, whereby up to 12 km of Meso- to Cenozoic sedimentary rocks accumulated. The study focused on the post-rift vertical movements along a typical "passive" margin and besides dealt with the timing and maximum temperature reached by potential source rocks of the basin. To unravel the t-T development, thermochronological analyses were performed on 50 outcrop and well samples from Meso–Cenozoic rocks. Thermochronological data reveal a continuous subsidence phase in the offshore basin from Mid-Triassic to recent times. In contrast, apatite (U-Th-Sm)/He and apatite fission-track data as well as thermal modelling point to an inversion of the northeastern onshore basin starting in the Palaeogene at 65–55 Ma. The rock uplift and exhumation period resulted in the erosion of a 1.0–1.4 km thick Cretaceous–Palaeogene sedimentary pile contemporaneously with peak Atlas surface uplift in the Cenozoic. The exhumation stage could be an explanation for the increasing periodic influx of detrital material into the offshore and southern onshore Tarfaya Basin since Palaeocene. Detrital apatite fission-track ages from 92 (± 16) to 237 (± 35) Ma of the Upper Cretaceous–Neogene succession indicate no heating above 60 °C confirming immature to early mature Cenomanian to Campanian and Eocene source rocks in the onshore Tarfaya Basin.

1. Introduction

The Moroccan segment of the Atlantic "passive" continental margin (PCM) extends over nearly 3000 km representing one of the oldest continental margins conjugate to the Nova Scotia margin in North America. "Passive" continental margins are "first-order" archives of the Earth's surface that store information of the interplay between endogenous and exogenous forces related to continental rifting, breakup, sea-floor spreading, post-breakup and climate changes during their evolution. Along strike the present elevation of PCM's in general varies from high elevations (> 1000 m a.s.l.) parallel to the shore line to very low elevations (< 50 m a.s.l.). The southern Moroccan PCM is characterized by low elevations (< 400 m a.s.l) that gradually increase towards the north (western Anti-Atlas, ~3000 m a.s.l.). The variation in topography indicates differentiated exhumation caused by e.g. the Alpine orogeny or the Canary mantle plume to the south. The study focused on the post-rift vertical movements along a typical "passive" margin.

The Tarfaya-Laâyoune-Dakhla Basin is the southernmost Moroccan Basin and stretches over 1000 km along the western Saharan margin from the Mauritanian border to the Canary Islands in the north (Fig. 1). The basin is bounded by the Mauritanides thrust belt and Precambrian Reguibat Shield in the ESE, the Palaeozoic fold belt of the Anti-Atlas in the NE and the East Canary Ridge in the NW (Fig. 1). The Tarfaya Basin is the northern part of the Tarfaya-Laâyoune-Dakhla Basin and stretches from Daora to Ifni along the western margin of the Sahara. Unfortunately, the thermal evolution of the basin is not well studied so far. Interestingly, the only appearance of oil as an indicator for higher temperatures is known from the offshore wells Cap Juby-1, MO-2 and MO-8 (Fig. 1). The oil is probably sourced from Upper Triassic or

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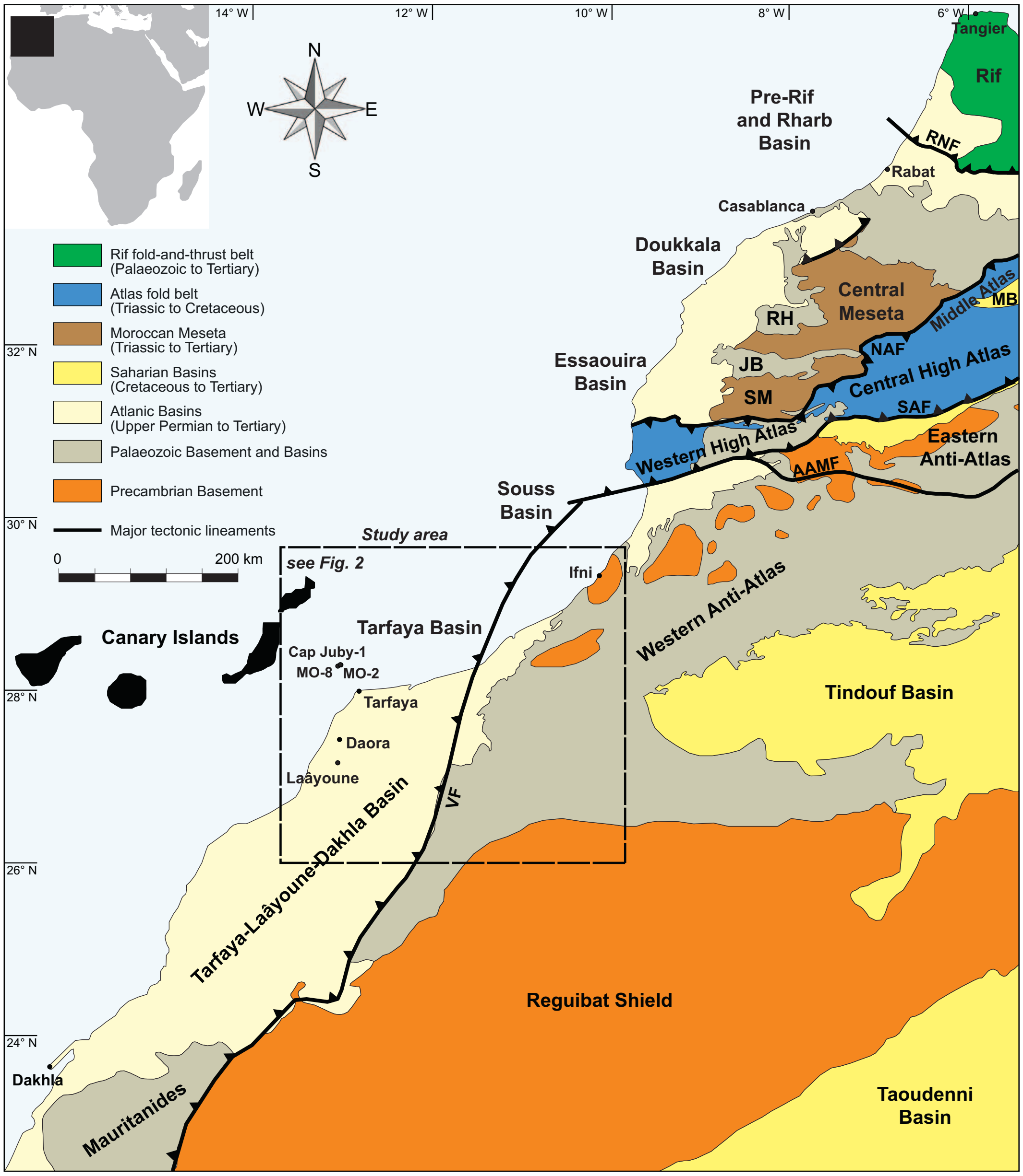

Fig. 1. Overview of the main tectono-sedimentary units of western Morocco and study area (Fig. 3). MB: Missour Basin; SM: Southern Meseta; JB: Jebilet; RH: Rehamna; RNF: Rif Nappe Front; NAF: North Atlas Front; SAF: South Atlas Front; AAMF: Anti-Atlas Major Fault; VF: Variscan Front (modified from Zühlke et al., 2004).

Jurassic carbonate layers (Davison, 2005; Jabour et al., 2000; Macgregor and Moody, 1998; Morabet et al., 1998; ONAREP, 2003) (Fig. 2). The second important scientific question addressed in this study is related to the timing and maximum temperature reached by the potential source rocks such as the Upper Cretaceous (particularly Cenomanian–Turonian) and Eocene stratigraphic intervals (Macgregor, 1996; Morabet et al., 1998) (Fig. 2).

The present study investigates the long-term landscape evolution of the southern Moroccan passive continental margin through low-temperature thermochronology (LTT). The determination of basin thermal history is essential for a better understanding of the source rock maturation in time and space. To improve the comprehension of the processes involved, the established and sensitive LTT methods, (U-Th-Sm)/He and fission-track dating were performed in the Tarfaya Basin. LTT techniques have been applied successfully to unravel rates of subsidence and exhumation in a variety of tectonic scenarios, such as passive margins (Gunnell, 2000). Thermochronological data were tested against various geological histories to quantify the time-temperature (t-T) evolution by using the software code 'HeFTy' (Ketcham, 2005; Ketcham et al., 2007a, 2007b, 2009).

2. Geological setting

The basin fill and evolution of the Tarfaya-Laâyoune-Dakhla Basin was subject of numerous studies. Subsidence analyses have been carried out from different areas of the basin indicating vast subsidence since the onset of rifting in Late Permian times (Ellouz et al., 2003; von Rad and Einsele, 1980; Wenke et al., 2013). The Central Atlantic rifting stage lasted until the Hettangian-Pliensbachian (200–190 Ma) (Labails et al., 2010; Zühlke et al., 2004). The initial ocean spreading started in the southern part between Western Sahara–Mauritania and the Baltimore Canyon, while the oldest oceanic crust is of Sinemurian to Late Pliensbachian age (195–184 Ma) (Le Roy et al., 1998; Steiner et al., 1998; Zühlke et al., 2004). Previous models suggested a later onset of sea-floor spreading in Toarcian to Bajocian times (178–169 Ma) (Klitgord and Schouten, 1986). Wenke et al. (2011) subdivided the