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The uplift history of the Arabian Plateau as inferred from geomorphologic analysis of its northwestern edge

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ABSTRACT

The Arabian Plateau (AP) is an Oligocene sub-horizontal regional planation surface, extending throughout the western half of the Arabian Peninsula. Its present elevation of about 1 km required a prominent uplift since the Late Eocene. In order to reconstruct the uplift history, we documented abundant abrasive and fluvial terraces that were left along and across the raised Judea Mountains (JM), which comprised the NW edge of the AP. Using the ages of those terraces and the differences in height between them, we found that the JM was uplifted in three major phases: a few hundred meters during the Late Eocene–Early Oligocene, ~500 m during the Early Miocene–early Middle Miocene, and ~350 m during the Late Pliocene. The two earliest uplift phases predate the formation of the Dead-Sea Transform (DST), which today separates the JM from the AP, meaning that these two phases affected the continuous rigid lithosphere extending southeastwards to the AP interiors. Moreover, restoration of the paleogeography predating the lateral offset along the DST eliminates the main height differences across it and suggests that the DST does not play a major role in the vertical position of its bordering plates, but rather forms a relatively narrow deformation strip within the AP. Those two early phases of uplift can be corroborated by previous thermochronology studies, which exhibit similar ages around the Red Sea but may reflect the uplift age of the entire region. The present sub-horizontal morphology of the AP is in contrast to the presumed original northeastward drainage and may suggest a subsequent long-wave moderate tilting to the SW. Three possible mechanisms were suggested for the uplift of the AP: a long wavelength flexure of the Arabian plate during early stages of the uplift, and lithospheric thinning or dynamic topography during later stages of the uplift.

1. Introduction

The Arabian Plateau (AP) is a regional elevated planation surface extending throughout the western half of the Arabian Peninsula (Fig. 1). Its elevation ranges between 800 and 1200 m and it is remarkably sub-horizontal although it extends over more than 1 million km^2 (Figs. 1, 2). The planation character of some areas in the AP has been noted in several studies (e.g., Quennell, 1958; Lebkicher et al., 1960; Beydoun, 1966; Powers et al., 1966; Brown et al., 1989; Burke and Gunnell, 2008; Avni et al., 2012). To the west and south, the AP is bounded by the elevated shoulders of the Red Sea and the Gulf of Aden. To the north and east the plateau gently descends towards the Persian Gulf and the Mesopotamian Basin. To the northwest, the AP has a relatively short boundary with the Mediterranean Sea, which is the area studied here. The planation surface of the AP developed over the Precambrian crystalline rocks of the Arabian–Nubian Shield and Phanerozoic sedimentary succession of the Arabian carbonate platform, truncating hard and soft rocks at a similar level (Fig. 2).

The age of the planation is constrained to the Oligocene since it truncates Middle Eocene marine rocks and is overlain by Miocene to Pleistocene volcanic rocks (Figs. 1, 2). However, the age of the uplift is unclear. It may have started in the Late Eocene when marine environments that had previously covered the wide Arabian carbonate platform started to wander towards its margins (e.g., Beydoun, 1991; Alsharhan and Nairn, 1997; Ziegler, 2001; Gvirtzman et al., 2011; Avni et al., 2012). However, it is not clear when and how fast the previously submerged AP was uplifted to its present elevation of ~1 km above sea level and whether this process was continuous or episodic.

Documenting uplift of a wide terrain such as the AP is crucial for understanding the geodynamic processes that governed it. However, this requires knowledge of the magnitude, age, and rate of uplift beyond the general constraint of ~1.5 km within ~35 my (Bar et al., 2013). More data about uplift and exhumation are available for East Africa (e.g., Coulie et al., 2003; Pik et al., 2003) and the Red Sea margins (e.g., Kohn and Eyal, 1981; Bohannon et al., 1989; Omar et al., 1989; Menzies et al., 1992, 1997; Steckler and Omar, 1994; Omar and Steckler, 1995; Bojar et al., 2002; Feinstein et al., 2013) for which apatite fission track analyses were performed. However, these data are all from the southern and southwestern fringing areas and its relevance for the main AP terrain is not sufficiently clear.

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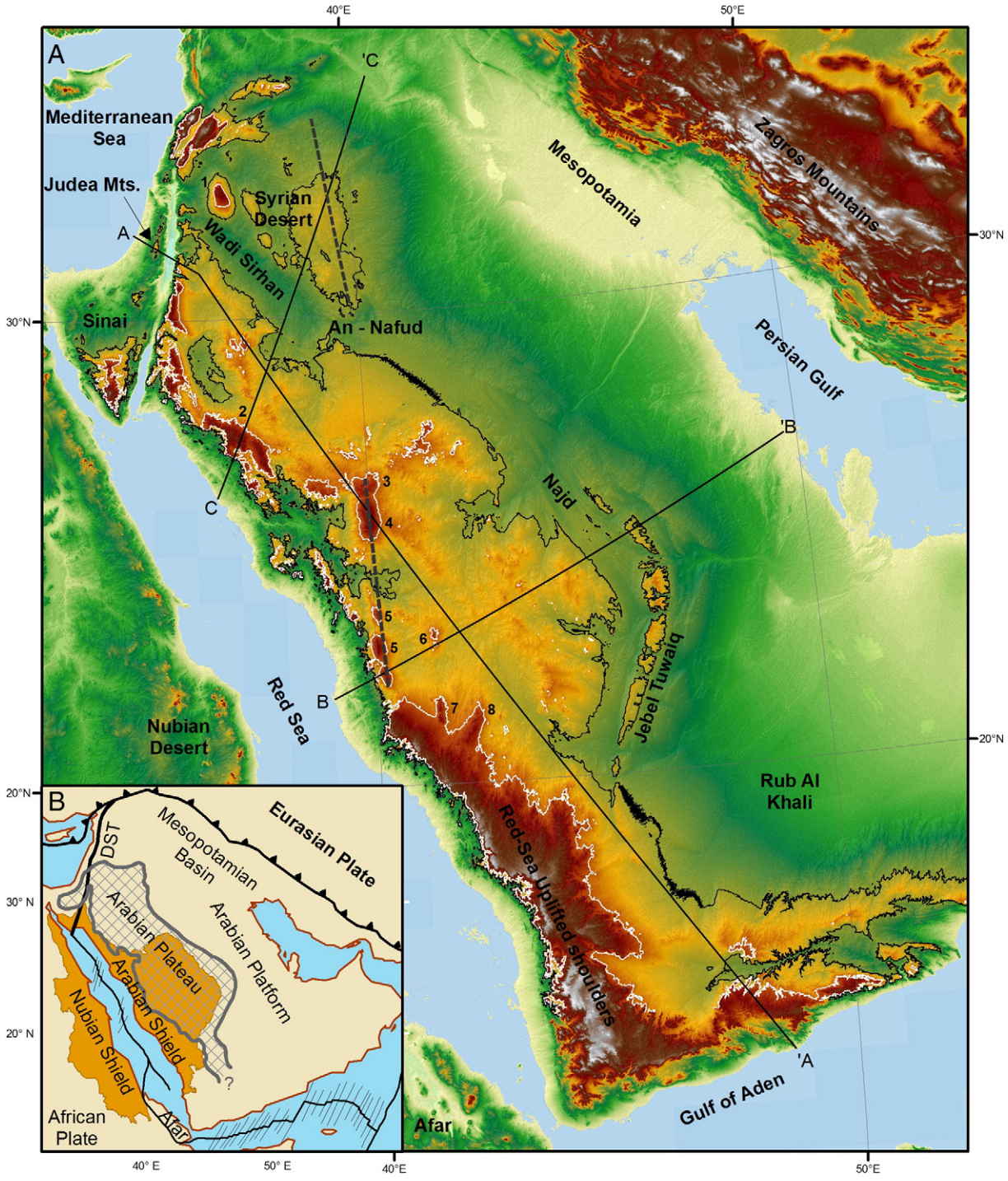

Fig. 1. A. Map of the Arabian Plateau (AP) and surrounding region. Black (800 m) and white (1200 m) contours roughly constrain the plateau. Black numbers indicate lava fields ("harrats") overlying the plateau: 1. Harrat ash Shama (13.4 ± 0.4 Ma to 4.9 ± 1.3 Ma); 2. Harrat ar Raha-Uwayrid (26.7 ± 2.6 to 7.4 ± 1.5 Ma); 3. Harrat Ithnayn and 4. Harrat Khaybar (11.5 ± 2.3 to 7.5 ± 0.8 Ma); 5. Harrat Rahat (13.2 ± 1.5 Ma to recent; base of its westernmost part is probably Oligocene); 6. Harrat Kishb (2 Ma to 2000 yr. B.P.); 7. Harrat Hadan (27.8 ± 1.4 to 3.4 ± 0.5 Ma); 8. Harrat Nawasif (4.4 ± 1.0 to 1.1 ± 0.3 Ma). Ages are after Brown et al. (1989); Camp and Roobol (1989) and Camp et al. (1992). Dashed gray line passing through 3–5 is the MMN (Makkah–Madinah–Nafud) line; dashed gray line crossing the CC′ section is the Ha'il-Rutbah arch (both lines after Camp and Roobol, 1992). Location of geological cross-sections of Fig. 2 is marked by solid black lines. B. Regional tectonic map of the Arabian Plate emphasizing the Arabian Shield (brown) and the Arabian Plateau (gray).

A common approach used for investigating uplift history of continental terrains is analysis of the drainage system response. However, since the response of intra-continental fluvial systems to uplift is relatively late, analysis of near-sea regions, which respond much faster to uplift, provides a better constrain for the uplift age. Sea-facing slopes are frequently carved by a series of abrasion terraces. Contemporaneously, rivers incising in these slopes leave a series of fluvial terraces along their valleys. Documenting the age of abandoned abrasion and erosion surfaces and height differences between them can be used to reconstruct uplift history.

Applying this methodology to the seaward facing slopes of the Arabian Peninsula along the elevated margins of the Red Sea and Gulf of Aden or towards the descending Mesopotamian Basin might be complicated due to effects of young tectonic processes, which deformed