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Early Neogene foreland of the Zagros, implications for the initial closure of the Neo-Tethys and kinematics of crustal shortening

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ABSTRACT

We study the transition from passive margin to foreland basin sedimentation now exposed in the High Zagros belt to provide chronological constraints on the initial stage of Arabia–Eurasia collision and closure of the Neo-Tethys. We performed magnetostratigraphy and strontium isotope stratigraphy along two sections near the Zagros suture which expose the oldest preserved foreland deposits: the Shalamzar section in the west and the Dehmoord section in the east. The top of the passive margin Asmari formation has an age of 28–29 Ma in the High Zagros and is overlain by foreland deposits with a major basal unconformity representing 7 Myr of hiatus. The base of the foreland deposits has an age of 21.5 Ma at Dehmoord and ca. 26 Ma at Shalamzar. The sedimentation rate increased from 30 m/Myr in the passive margin to 247 m/Myr in the foreland. Combined with available age constraints across the Zagros, our results show that the unconformity is diachronous and records the southwestward migration of the flexural bulge within the Arabian plate at an average rate of 24 ± 2 mm/yr over the last 27 Ma. The time evolution of sediment accumulation in the Zagros foreland follows the prediction from a flexural model, as the foreland is thrust beneath the orogenic wedge and loaded by the wedge and basin fill. We detect the onset of forebulge formation within the Asmari Formation around 25 Ma. We conclude that closure of the Neo-Tethys formed the Zagros collisional wedge at 27 ± 2 Ma. Hence, the Arabia–Eurasia collision was probably not the main driver of global cooling which started near the Eocene–Oligocene boundary (ca. 33.7 Ma). We estimate 650 km of forebulge migration since the onset of the collision which consists of 350 km of shortening across the orogen, and 300 km of widening of the wedge and increasing flexural rigidity of Arabia. We conclude the average rate of shortening across the Zagros to be ca. 13 mm/yr over the last 27 Myr; a value comparable to the modern rate. Palinspastic restoration of structural cross-sections and crustal volume conservation comprise only ca. 200 km of shortening across the Zagros and metamorphic Sanandaj–Sirjan belt implying that at least 150 km of the Arabian crust was underthrust beneath Eurasia without contributing to crustal thickening, possibly due to eclogitization.

1. Introduction

The timing of the Arabia–Eurasia collision along the Alpine–Himalayan orogen (Fig. 1) is highly controversial, with estimated ages ranging between 5 and 35 Ma (e.g., Allen and Armstrong, 2008; Bird et al., 1975; Dewey et al., 1973; McQuarrie and van Hinsbergen, 2013; Mouthereau et al., 2012; Saura et al., 2015). A more robust constraint of the timing is crucial for establishing correlations with shifts in climate and plate tectonic patterns. For example, form a climate perspective, it has been proposed that the closure of the Neo-Tethys drove Cenozoic cooling (Allen and Armstrong, 2008) because of the impact on volcanism, the draw-down of atmospheric CO_2 due to chemical weathering and burial of organic carbon associated with erosion of the collisional orogen, and the shutdown of the oceanic connection between the Indian and Atlantic Oceans. From a geodynamic perspective, several major regional changes occurred in the time span of the collision: (1) the upwelling of the Afar plume and the opening of the Red Sea around 30 Ma (Bosworth et al., 2005), (2) the slowdown of

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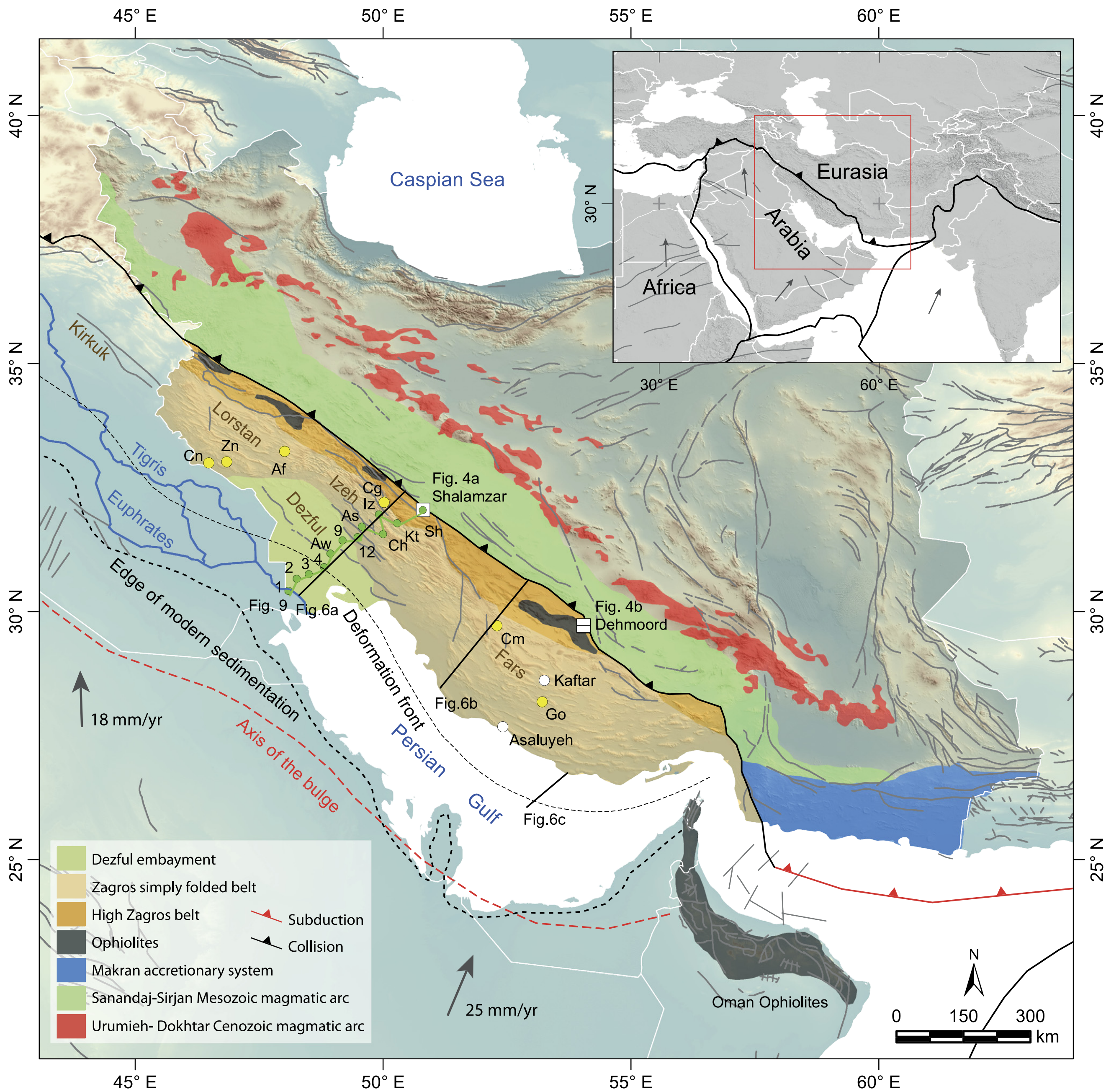

Fig. 1. Geological setting of the Zagros collision zone with locations of the dataset used in this study. White squares show locations of the studied magnetostratigraphic sections. Locations of previous published magnetostratigraphic studies are shown with yellow circles (Emami, 2008; Homke et al., 2004; Khadivi et al., 2010; Ruh et al., 2014). Abbreviations are: Af, Afrineh; Cg, Chaman–Goli; Cm, Chahar–Makan; Cn, Changuleh; Go, Gol–Gol; Zn, Zarinabad. Green circles show borehole locations and outcrops used for strontium isotope stratigraphy of the Asmari Formation (Ehrenberg et al., 2007; Van Buchem et al., 2010). Labels 1, 2, 3, 4, 9 and 12 refer to the boreholes and Aw, As, Ch, Iz, Kt and Sh stand for Ahwaz, Asmari, Chidan, Izeh, Katoola and Shalamzar sections. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

northward motion of Arabia relative to Eurasia between 28 Ma and 20 Ma (McQuarrie and van Hinsbergen, 2013), and (3) a possible more recent 15–20% slowdown of Arabia suggested by the comparison of modern kinematics from GPS geodesy with late Quaternary plate kinematics (e.g. Nocquet et al., 2006). At the more local scale of the Zagros and Iranian Plateau, there is geological evidence for a Paleogene volcanic flare-up that ceased around 40 Ma (Verdel et al., 2011) possibly due to slab steepening and final break-off in the Miocene (Omrani et al., 2008). These various events could all be related to a reorganization of mantle convection linking the Afar plume and slab roll back in the Aegean (e.g., Faccenna et al., 2013), and to the effect of the collision and slab break-off (Austermann and Iaffaldano, 2013). Establishing the causative links between these various geodynamic events and their relation to climate relies critically on their relative chronology. Improved chronology of the collision is also important for calculating the amount of crustal shortening and underthrusting of Arabian lithosphere since the closure of the Neo-Tethys.

In this study, we focus on improving the constraints on the initial stage of mountain building in the Zagros by investigating its earliest foreland basin deposits. We assume that the foreland evolves in relation to the orogenic wedge following a framework established from studies in other tectonic contexts (e.g., DeCelles and Horton, 2003). This model postulates that the foreland basin