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Detrital zircon (U–Th)/He thermochronometry of the Mesozoic Daba Shan Foreland Basin, central China: Evidence for timing of post-orogenic denudation

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ABSTRACT

The timing of the transition of a peripheral foreland basin from underfilled to overfilled provides important insights into the post-orogenic dynamics of its coupled orogenic wedge. Such information is lacking in the Mesozoic foreland basins surrounding the Qinling Orogen, central China, such as the Daba Shan Foreland Basin (DSFB), the northeastern part of the Sichuan Basin. In an effort to constrain the timing of maximum burial and onset of denudation, we report detrital zircon (U–Th)/He (ZHe) data from four deep boreholes in the DSFB. Results show that ZHe ages from the oldest foreland basin formations (Upper Triassic–lower Middle Jurassic) are mostly younger than their depositional age, whereas non-reset ZHe ages characterize younger strata. This suggests that the oldest strata attained maximum temperatures between ~130 °C and 200 °C (ZHe partial retention zone), which is consistent with previous independent paleotemperatures (organic matter reflectance and illite crystallinity) reported in two of the boreholes and another nearby. The fully reset ages apparently show the youngest peaks at ~80 Ma and ~100 Ma, which are interpreted as the minimum constraints on the timing of maximum basinal burial and subsequent denudation. Considering that the regional deposition has lasted to Aptian time, it is proposed that the onset of the basin exhumation in the DSFB started at Aptian–Albian time (~100–125 Ma), heralding the termination of regional tectonic shortening in the hinterland (Southern Qinling).

1. Introduction

Foreland basins stop subsiding and become overfilled, when topographic growth ceases in their coupled orogenic wedge (e.g. Allen et al., 1986; Beaumont, 1981; DeCelles and Giles, 1996; Garcia-Castellanos et al., 1997). This might be followed by an episode of significant denudation due to post-orogenic uplift (Garcia-Castellanos et al., 1997). Some reported potential driving forces of the uplift and denudation include: orogen denudation and viscous stress relaxation of flexured lithosphere (Garcia-Castellanos et al., 1997), gravitational crustal collapse (Rey et al., 2001; Teng, 1996), mantle upward flow (Roure et al., 2009) or changes in climate, which enhance the erosive powers of rivers and/or glaciations (Cederbom et al., 2004). Therefore, knowledge of the onset and magnitude of denudation in foreland basins is crucial for deciphering their geodynamic history (Allen and Allen, 2005; Bertotti et al., 2006; Merten et al., 2010). Such knowledge is also important for assessing basinal hydrocarbon potential (e.g. Corcoran and Doré, 2005; Macgregor, 1996).

In Mesozoic time, several foreland basins, such as the Daba Shan Foreland Basin (DSFB) and the Micang Shan Foreland Basin, formed along the northwestern margin of the Yangtze Block, central China (Fig. 1). These basins have been suggested to be responses to the formation of the Mesozoic Qinling Orogen triggered by the Mid-Late Triassic collision between the Yangtze and Sino-Korean Blocks (Yin and Nie, 1996; Zhang et al., 2001). Several lines of evidence, including stratigraphy, paleotemperature indicators and thermochronology, suggest that most of the basins have experienced significant denudation during the Cretaceous–Cenozoic (Guo et al., 1996; Meng and Zhang, 2000; SBGMR, 1991, 1997; Zhang et al., 2001). For example, in the DSFB, evidence from the distribution of relict strata suggests that deposition might have extended into the Early Cretaceous; however in a large part of the basin, Lower Cretaceous and even Jurassic strata have been partly or completely eroded, resulting in the exposure of older rocks at the surface (Fig. 1B) (Guo et al., 1996; SBGMR, 1991, 1997). Further, recent studies on paleotemperature indices (e.g. Hu et al., 2010; Qin et al., 2009), and apatite fission track (AFT) and (U–Th)/He (AHe) thermochronology provide strong evidence for the significant denudation

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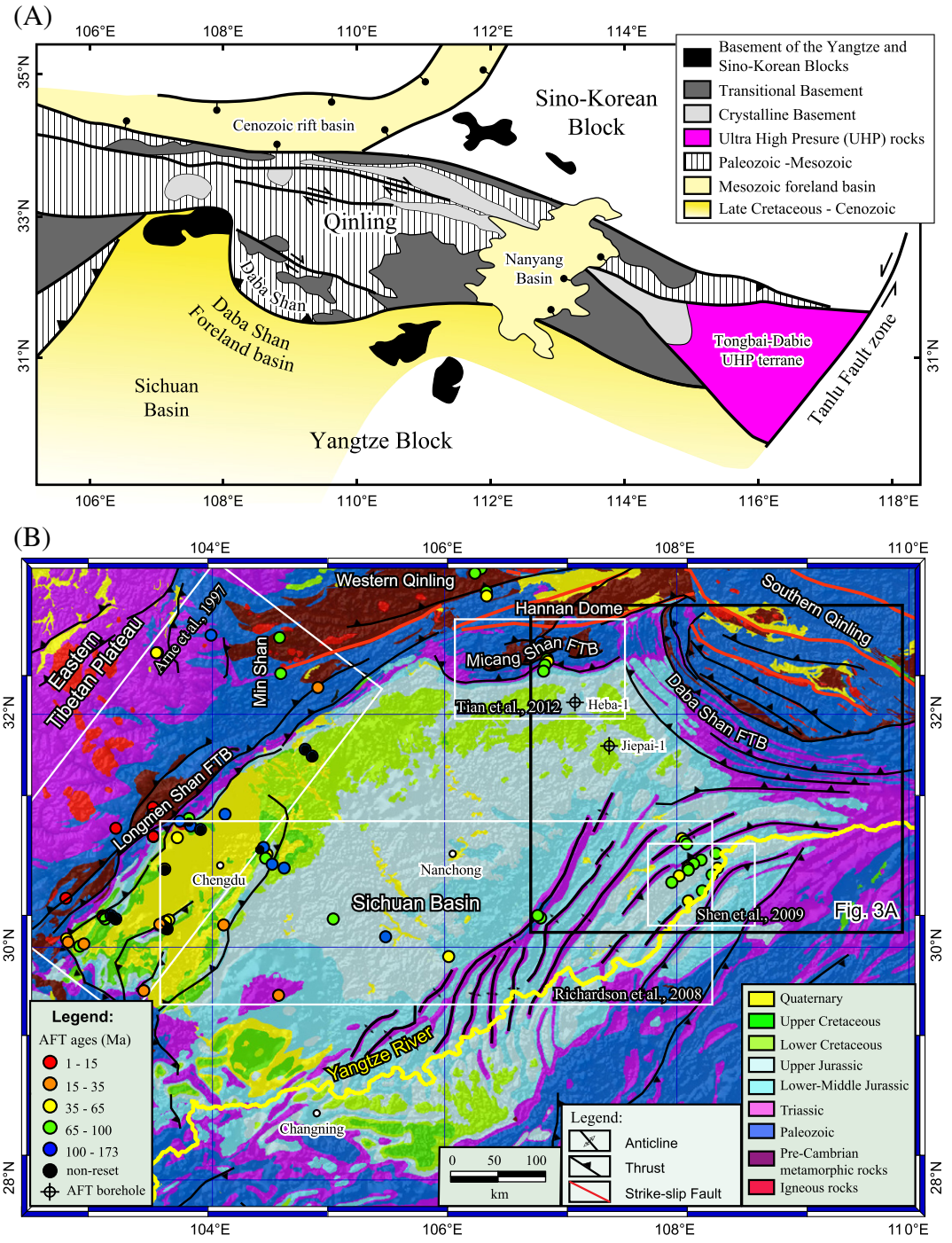

Fig. 1. (A) Generalized geological framework of the Qinling Orogen. Late Cretaceous structural features, e.g. half grabens (Nanyang Basin), dextral strike-slip faults (Ratschbacher et al., 2003; Zhang et al., 2001), are highlighted. (B) Generalized geological map of the Sichuan Basin and adjacent regions, superimposed on topography (Gtopo30) using ArcMap, and a compilation of published AFT data. Note that the formation age of outcrops changes systematically within the basin from Upper Triassic to Middle Jurassic in the east to Upper Jurassic to Cretaceous in the west, and Cenozoic in the southwest. The study area is outlined by a black box. Those areas for which AFT data has been reported are shown by white boxes with references indicated, and other areas outside boxes for which data are shown were reported by Enkelmann et al. (2006). Abbreviations: FTB = fold and thrust belt.
(A) is modified after Meng and Zhang (2000), Zhang et al. (2001) and Wang et al. (2003). (B) is modified after SBGMR (1991, 1997) and Zhang et al. (1992).

of the DSFB section since at least ~80 Ma (Richardson et al., 2008; Shen et al., 2009; Tian et al., 2011, 2012).

Knowledge of the denudation history of the Sichuan Basin (Fig. 1), comprising the DSFB and other sub-basins, is of critical importance in understanding post-orogenic denudation and dynamics of the basin and the corresponding hinterland, the Qinling Orogen (Enkelmann et al., 2006; Ratschbacher et al., 2003; Reiners et al., 2003). However, so far, no solid quantitative constraints for the onset and magnitude of the denudation of the DSFB have been reported. The AFT and AHe ages reported to date are all fully reset (Figs. 1B and 2), indicating that their host rocks were once buried to temperatures greater than those typically required for total annealing (>~110 °C). This also implies that previous reconstructions based on these data underestimated the denudation (Richardson et al., 2008; Shen et al., 2009; Tian et al., 2011, 2012).

Zircon (U–Th)/He (ZHe) and fission track (ZFT) thermochronometers, having higher nominal closure temperatures than apatite from the same systems, are potential tools for expanding the existing time–temperature