**Climate as the great equalizer of continental-scale erosion**

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**Additional Supporting Information (Files uploaded separately)**

Captions for Tables S1 to S2

**Introduction**

The following supporting information contains: The detailed location and age data for the thermochronology used in this study, and their associated publications. Some publications did not contain latitude and longitude data for their samples, in which case, the geological maps were georeferenced using QGIS. Paleogeographic reconstructions from G-Plates used to approximate paleo-latitude and longitude. Maps of the bouguer gravity anomaly across Central Asia and in comparison to individual thermochronometric ages. Methods for the paleoclimate simulations generated and the distribution of modern rainfall across Central Asia.

Text S1: Paleo-Climate modelling methods

The Cenomanian simulation uses the default configuration of the Community Earth System Model version 1 (CESM1) including component models of atmosphere, land, ocean, sea-ice, and rivers (Gent et al. 2011; Hurrell et al., 2013). Paleogeography comes from a low-resolution version of the Getech Plc reconstruction, which advances upon the methods documented in Markwick and Valdes (2004) and was first introduced in Lunt et al. (2016). CO2 is fixed at 1120 ppm, which is within the range of Cenomanian reconstructions (Wang et al., 2014), and the solar constant is reduced following Gough (1981). The fully coupled model configuration was run for 2,000 years, with a switch to prescribed vegetation after 1,500 years (Sewall et al., 2007). After 2,000 years, the atmosphere, land, and ocean are in near equilibrium (Landant et al., 2020). Simulated ocean temperature and circulation generally agree with proxy reconstructions (Tabor et al., 2016; Ladant et al. 2020); however, the simulation has a cool bias.

The Early Eocene simulation uses CESM1 with an updated atmosphere model (Community Atmosphere Model version 5; CAM5) than the Cenomanian simulation that uses CAM4 (Hurrell et al., 2013); other model components match the Cenomanian configuration. Model boundary conditions follow the Deep Model Intercomparison Project protocol (Lunt et al., 2017) including paleogeography and vegetation from Herold et al., (2014), preindustrial solar constant, and an atmospheric CO2 concentration of 855 ppm, which agrees with reconstructions (e.g. Anagnostou et al., 2016). This simulation was first run for 2,000 year in fully coupled model for the surface climate to reach quasi-equilibrium, then extended for 60 years in a slab ocean configuration with updated East Asian topography that better represents Eocene topographic reconstructions (Kapp and DeCelles, 2019). The large- scale climate of this simulation has been shown to well capture the warmth of the Early Eocene (Zhu et al., 2019; Lunt et al., 2020).

The Pliocene simulation uses the Community Earth System Model version 2 (CESM2) with major updates in the atmosphere and land models (Danabasoglu et al., 2020). The model is configured following the Pliocene Model Intercomparison Project version 2 protocol (Haywood et al., 2016). Modifications to the boundary conditions include paleogeography and vegetation from the Pliocene Research, Interpretation and Synoptic Mapping Project (Dowsett et al., 2016) and 400 ppm CO2. The model is run in a fully coupled configuration for 1,200 years to reach a quasi-equilibrium. Results show good agreement with temperature and precipitation reconstructions from the mid-Pliocene (Feng et al., 2020; Haywood et al. 2020).

For all simulations, the orbital configuration and greenhouse gas concentration, aside from CO2, are set to preindustrial values. Further, all model configurations use a ~1° resolution rotated pole grid for the ocean and sea ice. Similarly, for the atmosphere and land, the Cenomanian and Eocene simulations share a 1.9° latitude × 2.5° longitude finite-volume grid while the Pliocene simulation uses a 0.9° latitude × 1.25° longitude finite-volume grid. All of these model configurations have been shown to well simulate present-day and historic climate (Gent et al., 2011; Hurrell et al., 2013; Danabasoglu et al., 2020).

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Figure S1. Paleogeographical reconstruction of Central Asia using G-Plates following Matthews et al. (2016). Thermochronometric data can be found in Table S1.

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Figure S2. Scatter plots showing thermochronometric ages against Bouguer Gravity Anomaly (mGal). Bouguer gravity anomaly obtained from Bonvalot et al. (2012). Linear splines with 1 standard error were produced using R-studio.

Bonvalot, S., Balmino, G., Briais, A., Kuhn, M., Peyreﬁtte, A., Vales, N. & Sarrailh, M. (2012), ‘World gravity map’, Bureau Gravimetrique International (BGI), Map, CGMW-BGI-CNES728, IRD, Paris .

Figure S3. Map of Central Asia compared to the global bouguer gravity anomaly (Bonvalot et al. 2012). Thermochronometric ages and locations can be found in Table S1.

Bonvalot, S., Balmino, G., Briais, A., Kuhn, M., Peyreﬁtte, A., Vales, N. & Sarrailh, M. (2012), ‘World gravity map’, Bureau Gravimetrique International (BGI), Map, CGMW-BGI-CNES728, IRD, Paris .

Figure S4. Map of Central Asia compared to the annual rainfall (Dee et al. 2011). Thermochronometric ages and locations can be found in Table S1.

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Table S1. List of samples, latitude, longitude (WGS84), reported age, reported error, associated publication, and thermochronometric method. Publications can be found in Table S2. Apatite fission-track = AFT, apatite (U-Th)/He = AHe, zircon (U-Th)/He = ZHe.

Table S2. A complete list of publications used in this study. Publications which did not provide precise latitude and longitude measurements are noted. Thermochronometric ages can be found in Table S1. Apatite fission-track = AFT, apatite (U-Th)/He = AHe, zircon (U-Th)/He = ZHe.