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Cenozoic history of topography in southeastern Gorny Altai: thermochronology and resistivity and gravity records

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Abstract

The Central Asian Orogen was reactivated in the Cenozoic, which gave rise to mountain systems and sedimentary basins, strike-slip and thrust faults, ramps, and rift basins under the far-field effect of the India–Eurasia collision. Pre-Cenozoic structures, as well as the superposed Cenozoic deformation, are traceable in the gravity pattern. Analysis and correlation of stratigraphic, tectonic, geomorphological, and geophysical (resistivity and gravity) data from Gorny Altai and tectonic modeling on the basis of apatite fission-track thermochronology show that vertical motions have been the most active for the past 5 Ma. The uplift and subsidence produced, respectively, the Chulyshman and Ukok Plateaus with high mountains around and the the Kurai–Chuya basin between them. Gravity data suggest the existence of Late Carboniferous, Jurassic, and Cretaceous rocks found in tectonic wedges around the basin at the base of its sedimentary fill.

Keywords: neotectonics; plateau; strike-slip fault; thrust; ramp; fission-track thermochronology; resistivity and gravity fields; Gorny Altai

Introduction

The Central Asian Orogen was reactivated in the Cenozoic, and that activity produced mountain systems and sedimentary basins, strike-slip and thrust faults, ramps, and rift basins under the far-field effect of the Eocene India–Eurasia collision (Buslov et al., 2007, 2008; Buslov, 2012; De Grave et al., 2004, 2006, 2007a,b,c; Dobretsov et al., 1995, 1996; Molnar and Tapponnier, 1975; Novikov et al., 2014; Timofeev et al., 2014). Pre-Cenozoic tectonic structures as well as the superposed Cenozoic deformation (Fig. 1) are traceable in the global gravity field from double retracked satellite altimetry (Andersen et al., 2010). The zone of Cenozoic deformation extends from the Baikal rift system, with the largest Baikal basin (Fig. 1), to the Jonggar, Tarim, and adjacent basins around and within the Tien Shan mountains. This zone is geomorphically expressed as a domino-like system of basins and ranges and results from Miocene–Pleistocene movements propagating as successive uplift and subsidence off the collision zone: Tibetan Plateau and Tarim basin (microplate); Tien Shan mountains and Jonggar basin; Altai, East Sayan, and circum-Baikal ranges and pull-apart basins (Buslov et al., 2008; Buslov, 2012; De Grave et al., 2007a; Dobretsov et al., 1995, 1996, 2013; Glorie et al., 2012). The basins and ranges typically have rhombic contours, and some consist of smaller rhombic structures. The gravity contrasts are the highest in the Tien Shan and its surroundings (from –300 to +300 mGal) and as high as –250 to +200 mGal around Lake Baikal (Fig. 1). Outside the Cenozoic basins and ranges, the orogen comprises oval and curved features of fold-thrust belts cut by later strike-slip faults. This deformation style is especially well pronounced in East and West Mongolia, Tuva, and in the West and East Sayan. The Achinsk, Kuzbass, Minusa, Barnaul, and Kyzyl basins in the Altai–Sayan area, northwest of the Late Cenozoic deformation zone, are marked by moderate gravity lows (–50 or –60 mGal), but the anomalies reach –100 to –120 mGal in the Ubsu-Nur, Zaisan, and Balkhash basins adjacent to the zone of Cenozoic movements (Fig. 1).

In Gorny Altai, the amount of uplift and subsidence was the greatest in southeastern Gorny Altai near the Mongolian

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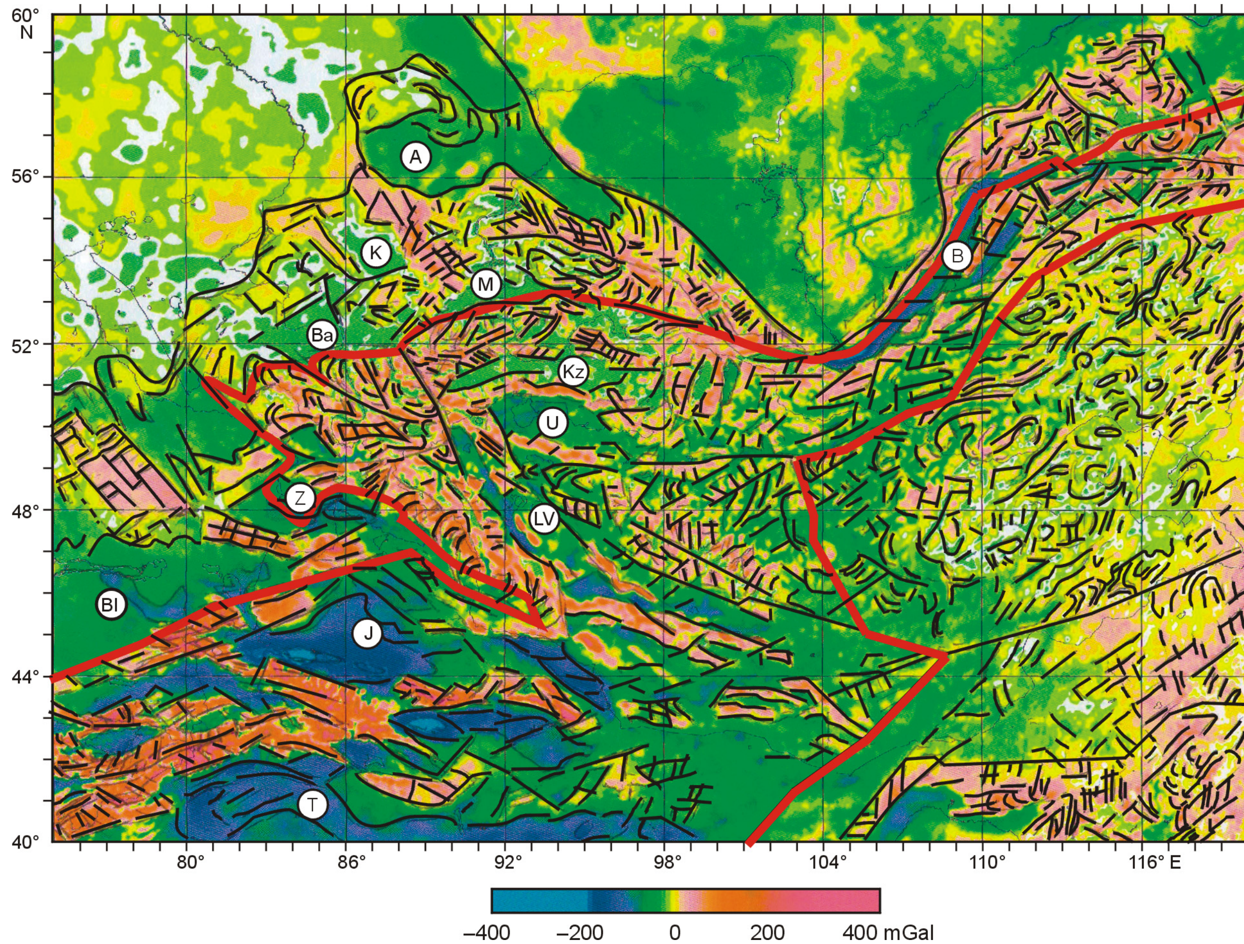

Fig. 1. Fragment of global gravity field (free-air gravity anomalies) for South Siberia, Tien Shan, and Mongolia (Andersen et al., 2010), with structural elements according to Dobretsov et al. (2013). Letters stand for names of basins: T, Tarim; J, Jonggar; Bl, Balkhash; Z, Zaisan; LV, Lake Valley; U, Ubsu-Nur; Kz, Kyzyl; Ba, Barnaul; K, Kuzbass; M, Minusa; A, Achinsk; B, Baikal. Red lines contour zone of strongest Cenozoic reactivation of pre-Cenozoic tectonic structures.

frontier (Fig. 2) and produced the Chulyshman (Kurai–Chulyshman block) and Ukok (eastern South Altai block) Plateaus with the flanking high mountains of North and South Chuya, Kurai, Shapshal, etc. and active faults between them. The faulting has followed the regional-scale Late Paleozoic Charysh–Terekta, Kurai, Teletsk–Bashkaus, and Shapshal faults (Buslov et al., 2003, 2013) and controls the historic seismicity (Agatova et al., 2014; Deev et al., 2015; Lunina et al., 2008).

We study the Cenozoic history of elevations in southeastern Gorny Altai using tectonic modeling on the basis of apatite fission-track thermochronology correlated with resistivity and gravity data from the Kurai–Chuya basin and the flanking mountains.

Thermotectonic modeling of elevations

The Cenozoic history of elevations is reconstructed using correlation of geological and geomorphological data (Buslov et al., 1999, 2003, 2013; Deev et al., 2012; Delvaux et al., 1995; Devyatkin, 1965; Dobretsov et al., 1995; Novikov et al., 1995; Zykin and Kazansky, 1995) with apatite fission-track thermochronology (De Grave and Van den Haute, 2002; De Grave et al., 2007b,c, 2008; Glorie et al., 2012) and subsequent thermal tectonic mapping (Vetrov et al., 2016).

The thermal history was studied in samples from the Kurai (Ku-43, Ku-84, Al-240) and South Chuya (G-07-04, Al-235) Ranges and from the basement beneath the Kurai basin (Ku-58). For the *Kurai Range* they were tonalite Ku-43 sampled at 50°06′18″ N, 88°30′52″ E, at an elevation of *h*-2557 m; diorite Ku-84 collected at 50°12′18″ N, 088°20′10″ E, and *h*-3024 m; and granodiorite Al 240 from 50°16′00″ N, 88°20′04″ E, and *h*-2440 m (Figs. 3, 4). The three samples shared a similar thermal history. The Early Cretaceous uplift (125 to 85 Ma) and the Cretaceous–Neogene quiescence (85 to 7 Ma) were followed by rapid cooling of rocks from 45 to 20 °C for the past 7 Myr (Late Miocene–Holocene) recorded in a steep rise of the time–temperature (*t*–*T*) curve. At a normal geothermal gradient of 25–30 °C per 1 km, the Kurai samples cooled by 25 °C during the past 7 Myr, while 825 to 1350 m of rocks were denuded. The cooling (denudation) rate at that stage was 7.6–3.6 °C/Myr (250–120 m/Myr). Ku-84 was sampled near the peneplain surface, and the denuded 825 m thick rocks above it were apparently Cenozoic sediments.