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Geomorphic Mesozoic and Cenozoic evolution in the Oka-Jombolok region (East Sayan ranges, Siberia)

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ABSTRACT

The East Sayan ranges are a key area to understand the interactions between the transpressive deformation linked to the far-field effects of the India–Asia collision and the extension linked to the opening of the Baikal Rift System. The active deformation that affects this range is very recent (around 5 Ma) but occurs in a very complex morphotectonic setting and the understanding of the Tertiary deformation relies entirely on a detailed knowledge of the pre-deformation situation. Using apatite fission track thermochronology, cosmogenic ^{10}Be and morphological study on Tertiary lava flows we demonstrate that prior to the Oligocene the morphology of the East Sayan area was characterized by a wide, constantly rejuvenated erosion surface. Apatite fission track thermal modelling indicates that this surface started to form at least in Late Jurassic–Early Cretaceous (140–120 Ma). The long-term exhumation rates (several tens of million years) derived from apatite fission track data (17.5 m/Ma) and the short-term erosion rates (over a few hundred thousand years) derived from cosmogenic ^{10}Be data (12–20 m/Ma) are coherent implying a near constant mean erosion rate since Late Jurassic. This constant, slow erosion prevented the formation of a lateritic–kaolinic weathering crust on the planation surface. By Oligocene–early Miocene times a long wavelength uplift that remains to be explained, induced incision that created shallow valleys later filled by basaltic lava flows. Finally, the present short-wavelength topography initiated during the Pliocene.

1. Introduction

West of Lake Baikal the major sinistral strike-slip Main Sayan fault reaches down to 50 km below the East Sayan ranges (San'kov et al., 2004) and separates the thick and rigid Siberian craton from the thinner, actively deforming Mongolian lithosphere (Delvaux et al., 1995, 1997; Gusev and Khain, 1996; Petit and Déverchère, 2006) (Fig. 1). The thickness of the crust vary from about 40 km north of the Main Sayan fault in the Siberian craton to about 50 km to the south in the East Sayan ranges (Polyansky, 2002). The Main Sayan fault can thus be considered as at least reaching the lithosphere. South of this fault, the Sayan ranges form an about 750 km long and 250 km wide complex that reach altitudes up to 3500 m. This elevated belt connects to the SE with the southern edge of the Baikal Rift System.

The active deformation that affects the Sayan ranges is very recent (less than 5 Ma) and results from the far field effects of the India–Asia collision to the south (Larroque et al., 2001; De Grave and Van den haute, 2002; De Grave et al., 2003; Arzhannikova et al., 2011). This transpressive deformation generates strike-slip and thrust faults within the whole Sayan ranges. However, the East Sayan ranges close to the Baikal Rift System are also locally affected by transtension leading to the formation of the Jombolok basin (Fig. 1). Arzhannikova et al. (2011) recently demonstrated that this transtensive structure results from strike-slip movements and block rotations along major E–W faults accommodating the large-scale SW–NE compressive deformation. Extension in the East Sayan ranges is thus directly linked to the far field effects of the India–Asia collision and does not result from the older still poorly understood mechanism that drove the initial opening of the Baikal Rift System (Jolivet et al., 2009).

Several studies have shown that during the Tertiary the motion along the major faults in the East Sayan ranges changed through time. For example the Tunka left-lateral normal fault (Fig. 1) that

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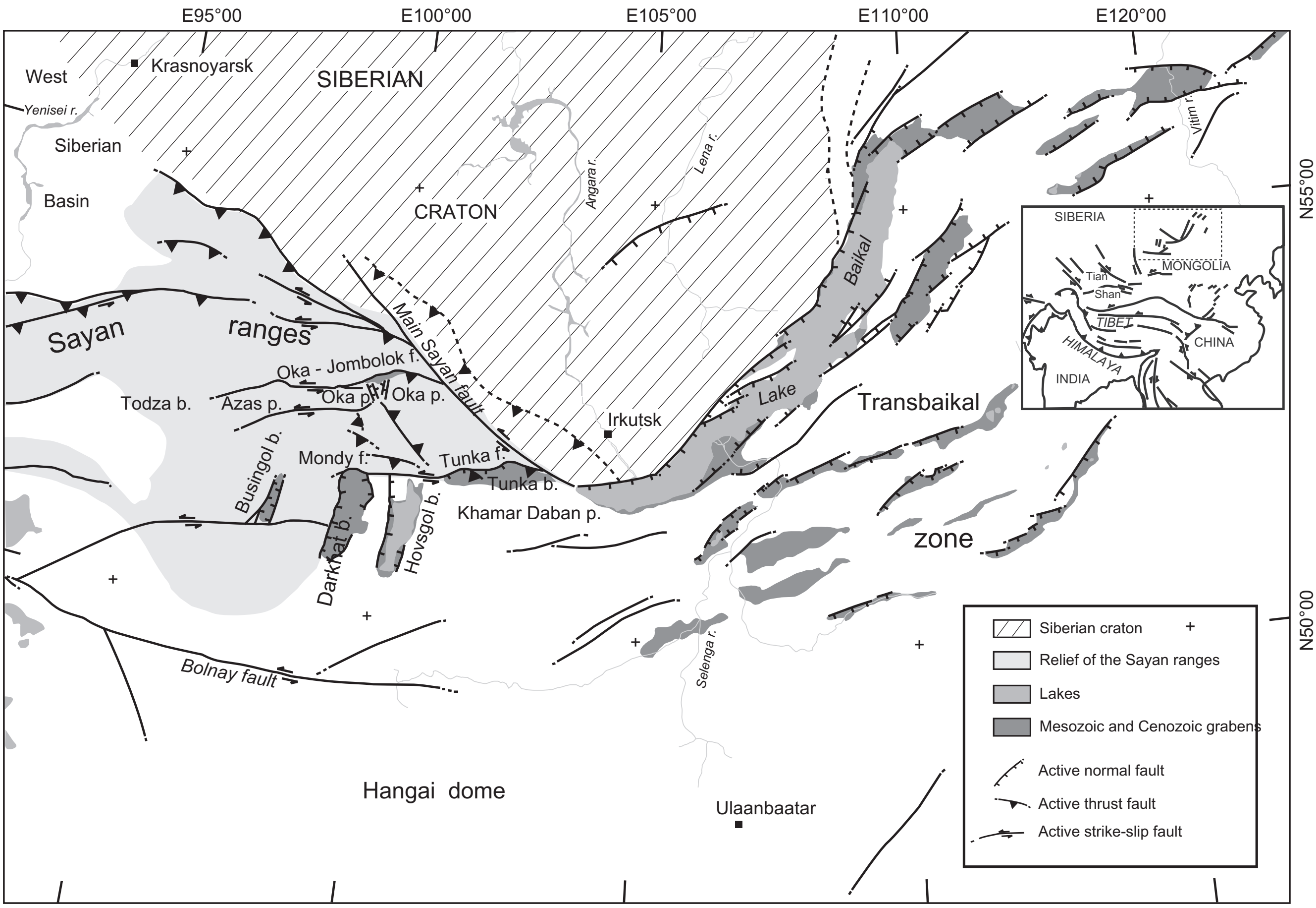

Fig. 1. General tectonic map of the Sayan and Transbaikal area. Note the contrasting tectonic regime between the transpressive Sayan region west of the southern edge of the Siberian craton and the extensive Baikal Rift System to the east. f. stands for fault; p. stands for plateau; b. stands for basin.

controls the formation of the Tunka basin shows evidence of recent (Late Pleistocene–Holocene) inversion (Larroque et al., 2001). Vertical movements along the Jombolok fault (Fig. 1) during the Late Pliocene to Pleistocene led to the growth of the Kropotkin range but since Late Quaternary, the movement becomes mainly horizontal (Arzhannikova et al., 2011).

The morphology of the East Sayan ranges is also very complex. Highly incised subranges like the Tunka or Kropotkin ranges culminating at altitudes over 3000 m coexist with large plateau-like areas such as the Oka plateau that has a mean altitude of about 2200 m (Fig. 1). The surface of those plateaus corresponds to the remnants of a large-scale peneplanation surface apparently similar to the one developed in southern and western Mongolia during the Jurassic (Jolivet et al., 2007). However, the lateritic-kaolinic weathering crust that developed on some of these surfaces (especially to the east in the Khamar Daban area (Fig. 1)) has been dated to the late Cretaceous–Palaeogene (Mats, 1993; Kashik and Masilov, 1994; Logatchev et al., 2002) indicating that it may be younger than the Mongolian peneplanation surface.

The East Sayan ranges are a key area to understand the interactions between the transpressive deformation linked to the far-field effects of the India–Asia collision and the extension linked to the opening of the Baikal Rift System. However, due to the complex morphotectonic setting of this region the complete understanding of the Tertiary deformation in the East Sayan ranges relies entirely on a detailed knowledge of the pre-deformation situation. The purpose of this work is to establish the morphology of the Oka-Jombolok region prior to the onset of the Tertiary deformation in order to estimate which part of the present morphology may be inherited from previous deformation and uplift events and which part results from Tertiary deformation. To reach that goal we combine regional morphotectonic analysis with both thermochronological data from apatite fission tracks analysis and shorter-term denudation rates derived from cosmogenic ^{10}Be analysis (Fig. 2). While apatite fission track analysis allows calculating exhumation rates over several tens to hundreds million years (e.g. Jolivet et al., 2001, 2009, 2010; Vassallo et al., 2007a), the cosmogenic ^{10}Be analysis provides erosion rates over a period of a few hundred thousand years to about 1 Myrs (e.g. Lal, 1991; Brown et al., 1991; Siame et al., 2004; Vassallo et al., 2007b). Detailed morphological analysis of numerous lava flows present in the region coupled to the thermochronology analysis allow deciphering the Mesozoic–early Cenozoic tectonic and geomorphic evolution of this complex region of the East Sayan ranges.

2. Geological setting

2.1. Summary of the existing information on the Mesozoic to Early Cenozoic geomorphology of the East Sayan ranges

No or nearly no Jurassic sediments are exposed in the East Sayan region and all the existing paleogeographic reconstructions are based on the Jurassic deposits of both the Pre-Sayan trough on the Siberian platform and the Todza basin immediately west of the Azas volcanic region (Fig. 1). Following those reconstructions tectonic movements induced the formation of a sharp, elevated relief during the Jurassic. Erosion of that relief is represented by