Tectonophysics 602 (2013) 194–222

Contents lists available at SciVerse ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Basin evolution in a folding lithosphere: Altai–Sayan and Tien Shan belts in Central Asia

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ARTICLE INFO

Article history:
Received 26 July 2012
Received in revised form 3 January 2013
Accepted 7 January 2013
Available online 24 January 2013

Keywords:
Continental lithospheric deformation
Folded lithospheric basins
Tectonic stress
Neotectonics
Central Asia

ABSTRACT

Central Asia is a classical example for continental lithospheric folding. In particular, the Altay–Sayan belt in South-Siberia and the Kyrgyz Tien Shan display a special mode of lithospheric deformation, involving decoupled lithospheric mantle folding and upper crustal folding and faulting. Both areas have a heterogenous crust with a long history of accretion–collision, subsequently reactivated as a far-field effect of the Indian–Eurasian collision. Thanks to the youthfulness of the tectonic deformation in this region (peak deformation in late Pliocene–early Pleistocene), the surface expression of lithospheric deformation is well documented by the surface topography and superficial tectonic structures. A review of the paleostress data and tectono-stratigraphic evolution of the Kurai-Chuya basin in Siberian Altai, Zaisan basin in Kazakh South Altai and Issyk-Kul basin in Kyrgyz Tien Shan suggests that they were initiated in an extensional context and inverted by a combination of fault-controlled deformation and flexural folding. In these basins, fault-controlled deformation alone appears largely insufficient to explain their architecture. Lithospheric buckling inducing surface tilting, uplift and subsidence also played an important role. They form typical basins in a folding lithosphere (FLB). Their characteristic basin fill and symmetry, inner structure, folding wavelength and amplitude, thermal regime, time frame are examined in relation to basement structure, stress field, strain rate, timing of deformation, and compared to existing modelling results.

1. Introduction

Both the oceanic and continental lithosphere are known for being able to deform by periodic instabilities, or folding, when submitted to horizontal stresses (Burg et al., 1994; Caporali, 2000; Lefort and Agarwal, 1996; Martinod and Davy, 1994; Sokoutis et al., 2005; Stephenson and Cloetingh, 1991; Zuber, 1987). As soon as the first observations of large lithospheric folds in the oceanic and continental lithosphere have been reported (Stephenson and Lambeck, 1985; Weissel et al., 1980) and the capability of the continental lithosphere to deform with periodic instabilities during compression has been demonstrated theoretically and by analogue modelling (Biot, 1961; Martinod and Davy, 1992), Central Asia became rapidly considered as a type region for large-scale lithospheric folding (Burov and Molnar, 1998; Burov et al., 1993; Nikishin et al., 1993). Since then, lithospheric folding has been recognized as an important mode of basin formation in compressional intraplate settings in an increasingly number of case studies (Cloetingh et al., 1999, 2002). Recently, Cloetingh and Burov (2011) introduced the concept of Folded Lithospheric Basins (FLB) for the basins that developed in a folding lithosphere. In the meantime, in the type region of Central Asia, knowledge of the tectonic context, time frame, stress field and basin evolution greatly improved. It appears therefore necessary to revisit the geological and geophysical evidence for lithospheric folding and characterize in more details basins developing in a folding lithosphere.

Central Asia is a particularly interesting region for investigating the combination of upper crustal faulting and continental lithospheric buckling thanks to its tectonic youthfulness. The peak of tectonic deformation that caused contractional deformation in the Altai–Sayan and Tien Shan regions in relatively young (late Pliocene–early Pleistocene), as evidenced by structural field work, stress field investigation, magnetic stratigraphy and thermochronology. Thanks to this youthfulness, erosion and sedimentation remained modest and the surface expression of lithospheric deformation is still well documented by the landscape topography and superficial structures.

The intramontane basins of Kurai-Chuya in the Siberian Altai, Zaisan in the Kazakh South Altai and Issyk-Kul in the Kyrgyz Tien Shan

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http://dx.doi.org/10.1016/j.tecto.2013.01.010

developed in a compressional to transpressional context and have been described as ramp or half-ramp basins bounded by thrust faults between rising mountain ranges as documented for the Kurai-Chuya basin system (Buslov et al., 1999; Delvaux et al., 1995c; Thomas et al., 2002), Zaisan basin (Thomas et al., 2002) and Issyk-Kul basin (Chedia, 1986; Cobbold et al., 1993; Sadybakazov, 1990; Thomas et al., 1993).

Detailed field structural and fault kinematic investigations completing recently published results on thermochronology, heat flow, GPS geodesy, seismic studies and geoelectric sounding provide new constraints that allow re-evaluating the formation mechanisms of these basins. None of the current end-members models for basin development in compressional context (foreland, pull-apart, ramp-type basins) satisfactorily explain the range of observation data. In this paper, we test whether these basins could be better explained by combining lithospheric folding and upper crustal faulting processes in a way proposed for Folded Lithospheric Basins (FLB) by Cloetingh

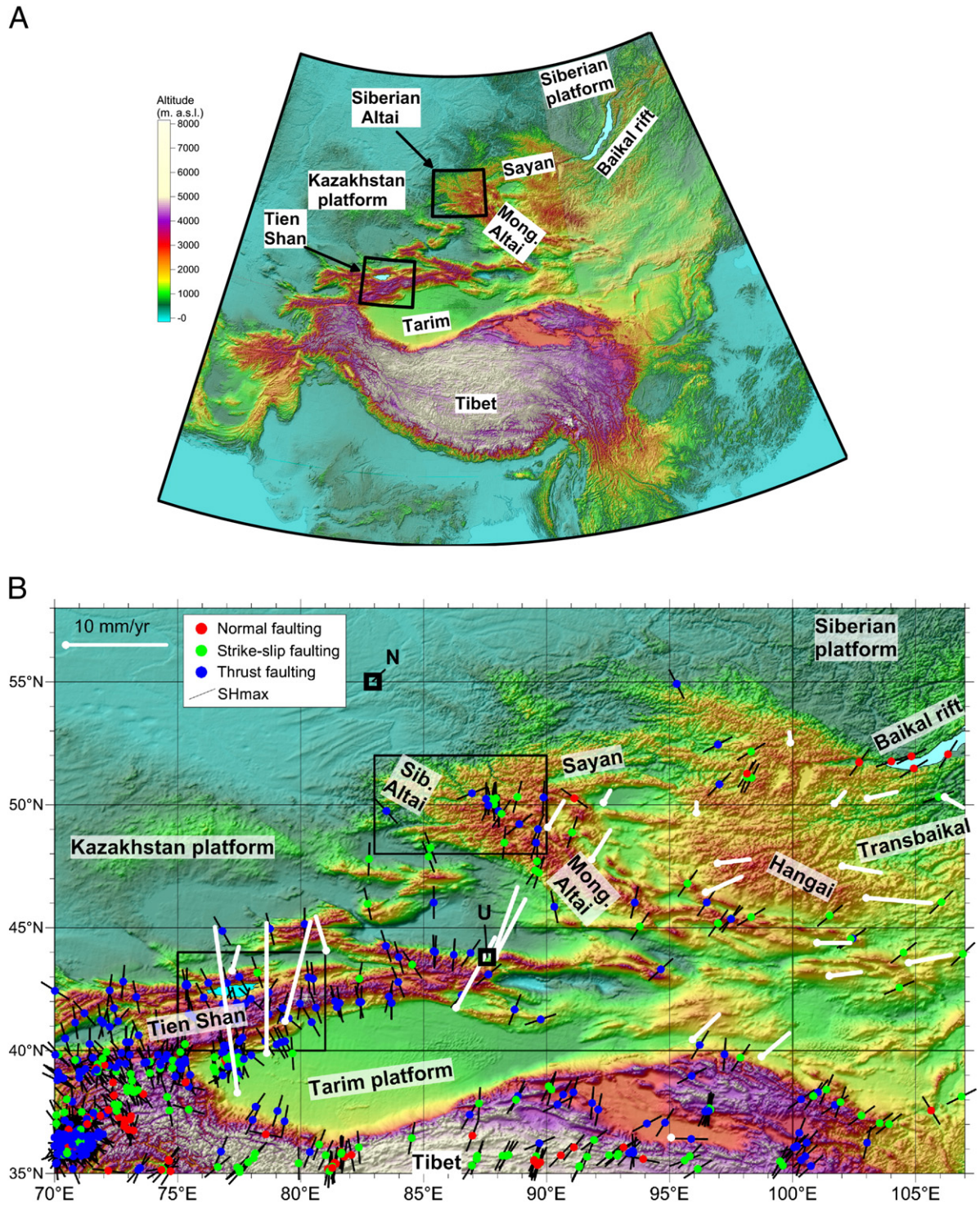

Fig. 1. Major structures of Central Asia in (A) Altai–Sayan in South Siberia and NE Kazakhstan and (B) Kyrgyz Tien Shan. Background color in function of elevation (from GTOPO-30). Dots showing location of earthquake focal mechanisms with color in function of type and black lines indicating S_{Hmax} direction (from Harvard CMTS). White lines with dot mark GPS derived slip vectors. Black squares, Novosibirsk (N) and Urumqi (U) towns.