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Total and incremental left-lateral displacement across the East Gobi Fault Zone, southern Mongolia: Implications for timing and modes of polyphase intracontinental deformation

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ABSTRACT

The East Gobi Fault Zone (EGFZ) is a dominant structural feature in southeastern Mongolia. The EGFZ's protracted history includes at least five distinct deformation events occurring over the last 250 million years. Two of these phases are marked by left-lateral motion, but the total and incremental displacement history is poorly known. A better understanding of the displacement history across the EGFZ is required to place its Mesozoic and Cenozoic evolution within the larger context of central Asian tectonics, including evaluating the EGFZ's possible role as an intracontinental extrusion feature. This study presents analysis of sedimentary and igneous rocks as proposed offset markers on either side of the EGFZ. New geochronologic data, integrated with existing structural and stratigraphic data, are used to characterize and quantify two periods of left-lateral displacement along the EGFZ. The slip history of the EGFZ includes a total of ~250–300 km of left-lateral displacement. Approximately 150–200 km of slip occurred along a major shear zone during the Late Triassic (~225–210 Ma), based on restoration of Carboniferous intrusive suites and Permian remnant ocean basin deposits. During this first period of left-lateral displacement, the EGFZ acted as a continental extrusion feature responding to oblique collision between the South and North China Blocks and northern Mongolia and Siberia, an event analogous to the later India–Asia collision during the Cenozoic. A second period of ~90–100 km of left-lateral slip occurred in the Late Oligocene, based on offset of Lower Cretaceous strata and cross-cutting relationships. This brittle deformation phase was contemporaneous with dynamic boundary conditions along the Pacific margin, and the Indo–Asia collision. Cenozoic movement along the EGFZ may have coincided kinematically with the Altyn Tagh Fault in China via dispersed fault zones in the Alxa region. Major displacement along the EGFZ likely ceased in the early Miocene, coincident with changing relative plate motions at the Pacific margin. Magnitudes of Cenozoic offset across the EGFZ are significantly smaller than estimated for the Altyn Tagh Fault, which likely reflects distributed deformation in heterogeneous crust of the southern Central Asian Orogenic Belt.

1. Introduction

Large-scale strike-slip fault systems are widely studied geologic features throughout central Asia. Faults reaching hundreds of kilometers in length are commonly cited in one of two end-member models for describing Cenozoic deformation throughout central Asia: lateral extrusion (Tapponnier et al., 1982) versus lithospheric thickening (Molnar et al., 1993). Major features such as the Altyn Tagh and Red River faults are subject to much scientific scrutiny (Allen et al., 1984; Tapponnier et al., 1986; Leloup et al., 1995; Yin et al., 2002; Cowgill et al., 2003; Schoenbohm et al., 2006; He and Chéry, 2008; Searle et al., 2010; Yin, 2010), whereas smaller faults and fault systems along the periphery of the Tibetan Plateau remain relatively under-explored.

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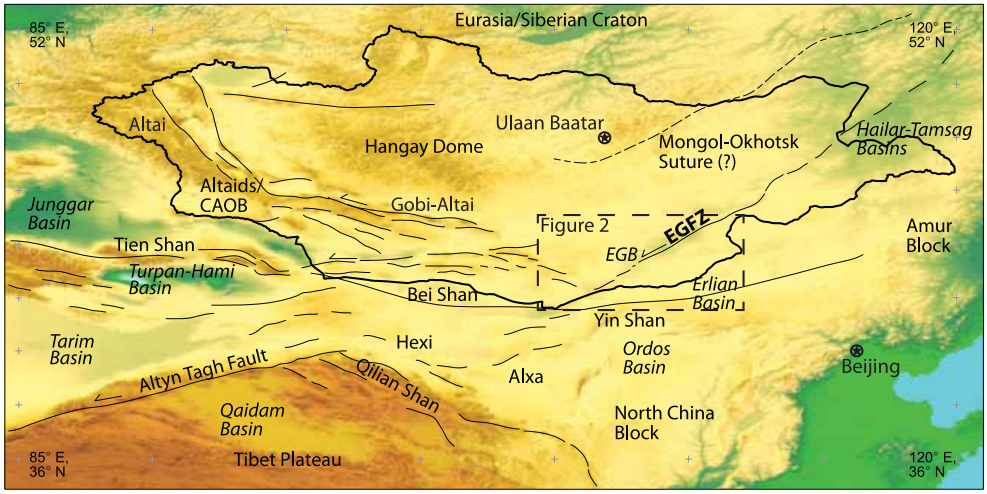

Fig. 1. Digital elevation model and major tectonic elements of Mongolia and surrounding regions (Badarch et al., 2002; Heumann et al., 2012; Cunningham, 2013). The abbreviation EGB = East Gobi Basin. Faults, tectonic blocks, basins, sutures and other features of relevance are shown. The approximate location of Fig. 2 is identified by the dashed box.

Western Mongolia is defined by a series of major Cenozoic strike-slip fault systems (Cunningham et al., 2003; Bayasgalan et al., 2005; Walker et al., 2007). In contrast, eastern Mongolia is generally marked by subdued topography and is not generally considered to be a region of active faulting or seismic activity (ANSS, 2010). Recent studies of the East Gobi Fault Zone (EGFZ) in southeastern Mongolia identify it as another important left-lateral strike-slip fault system in central Asia (Fig. 1; Lamb et al., 1999; Johnson, 2004; Webb and Johnson, 2006). Unlike the Altyn Tagh Fault and other regional Cenozoic structures, the EGFZ is a long-lived (>200 million years), polyphase fault zone, characterized by at least five periods of reactivation including two major phases of left-lateral displacement (Webb and Johnson, 2006; Webb et al., 2010).

The EGFZ's larger-scale tectonic significance is poorly understood, yet the fault zone has figured prominently in various interpretations of intracontinental deformation (e.g., how it relates to Cenozoic continental extrusion), with major temporal and kinematic implications for tectonic restorations (Jolivet et al., 1994; Fournier et al., 1994; Yin and Nie, 1996; Yue and Liou, 1999; Lamb et al., 1999; Yue et al., 2001; Zhang et al., 2009; Zhou et al., 2012). Such interpretations are partly based on pre-displacement reconstructions using geometric similarities of features inferred from remote-sensing datasets and geologic maps. Particularly in southeastern Mongolia, these inferences lack support from detailed field and analytical data. As a result of this ambiguity, displacement estimates range from ~200 km across the EGFZ mainly in the early Mesozoic, to ~400 km of combined Altyn Tagh-EGFZ displacement during the Cenozoic (Lamb et al., 1999; Yue and Liou, 1999). With the increase of geophysical and geologic investigations throughout southern Mongolia (driven in part by petroleum and minerals exploration; Penttila, 1994; Watanabe and Stein, 2000; Perello et al., 2001), these interpretations can now be tested more rigorously.

This study represents the first attempt to use reconstruction of basin-scale depositional systems, U–Pb detrital zircon geochronology, U–Pb zircon geochronology of igneous suites, and structural analysis to measure total and incremental left-lateral displacement across the EGFZ in Mongolia. Specifically, we seek to test two pairs of late Paleozoic units (one sedimentary and one igneous) on either side of the fault zone to quantify total displacement. These units were proposed by Lamb et al. (1999) to be offset by strike-slip displacement. An additional set of Lower Cretaceous sedimentary deposits are also evaluated to resolve incremental displacement across the EGFZ. The term 'piercing point' is used loosely here: these are not necessarily discrete features cut by a single fault (cf. Matthews, 1973). Nevertheless, reconstruction of sedimentary basin deposits and related features places limits on the EGFZ's displacement history. Similar approaches to this study have been employed for testing paleogeographic restoration of terranes in central Asia (Yue et al., 2005) and in other geographic regions where complex tectonic settings mask obvious correlation features (e.g., Baja-British Columbia reconstructions; Cowan et al., 1997; Housen and Beck Jr., 1999; Mahoney et al., 1999; Barbeau et al., 2005).

With new data presented here, this study seeks to better place the EGFZ within the temporal and kinematic framework for deformation in central Asia. Results bear on paleogeographic restorations and ongoing debates regarding the EGFZ's potential Cenozoic relationship with the Altyn Tagh Fault and other regional fault systems, and thus on larger scale processes related to continental growth and evolution.

1.1. Geologic setting

The East Gobi Fault Zone lies near the southern boundary of one of the largest accretionary complexes in the world, the Altaids or Central Asian Orogenic Belt (CAOB; Şengör et al. 1993a, 1993b; Windley et al., 2007). The CAOB formed by generally southward-stepping accretion of arc and microcontinent terranes throughout the Paleozoic, culminating along its southern margin with the arc-continental collision of the North China Block with extinct Paleozoic arcs in southern Mongolia in the Late Permian (Fig. 1; Nie et al., 1994; Yin and Nie, 1996; Şengör and Natal'in, 1996; Cope et al., 2005; Johnson et al., 2008; Jian et al., 2010; Heumann et al., 2012). Following terminal collision between southern Mongolia (the southern CAOB) and the North China Block, at least five phases of deformation occurred along the EGFZ during the Mesozoic and early Cenozoic. Each deformation phase is recorded in the Paleozoic basement and younger basin-fill strata of the East Gobi Basin (Fig. 2). Briefly, these include: Late Triassic sinistral shearing, Early Jurassic crustal shortening and foreland basin development, Late Jurassic–Early Cretaceous extension, middle Cretaceous compression and basin inversion, and Late Cretaceous–Cenozoic left-lateral strike-slip faulting (Graham et al., 2001; Johnson, 2004; Webb and Johnson, 2006; Webb et al., 2010; Heumann et al., 2012). Of the five deformation phases, the episodes of sinistral shearing and left-lateral strike-slip displacement (Late Triassic and Late Cretaceous–Cenozoic) across the EGFZ remain the least constrained.