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E–W extension at 19 Ma in the Kung Co area, S. Tibet: Evidence for contemporaneous E–W and N–S extension in the Himalayan orogen

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ABSTRACT

Active faulting in southern Tibet consists of N–S trending extensional faults and linked strike-slip faults, which are an expression of regional E–W extension. A second type of extensional deformation associated with N–S movement is also recognized. This extension is expressed as a series of shear zones and normal faults in the High Himalayas – the Southern Tibetan Detachment System – and mid-crustal rocks exposed in metamorphic domes. Reported constraints on the timing of movements associated with these two phases of extension indicate that N–S extension predates the onset of E–W extension. However, only a few studies have provided clear constraints on the timing of E–W extension and the extent to which the two kinematically distinct domains of extension were contemporaneous is unclear.

The Kung Co fault in southern Tibet is a major N–S trending normal fault. The associated E–W extension is locally expressed as high-strain ductile deformation. Both field and microstructural observations show that this deformation occurred synchronously with granite intrusion. Previously reported U–Pb zircon dating shows granite crystallization took place at around 19 Ma, implying that ductile E–W extension in the Kung Co area was also active at around 19 Ma. This is the oldest documented example of E–W extension in Tibet and shows that E–W extension was at least locally contemporaneous with N–S extension to the south at shallower crustal levels. Simultaneous mid-crustal N–S extension and upper crustal E–W extension may be explained by southward flow of Tibetan crust with a divergent radial component.

1. Introduction

Active tectonics in the central part of the Tibetan Plateau is dominated by a linked set of NE–SW and NW–SE trending strike-slip faults and N–S trending normal faults (Fig. 1) (Blisniuk et al., 2001; Taylor et al., 2003). The normal faulting acts to reduce the overall height of the Plateau despite the ongoing convergence of India with Asia and together with the strike-slip faulting reflects a regional E–W extension (e.g. Armijo et al., 1986). The onset of normal faulting in central Tibet marks a time when the horizontal deviatoric stresses in the plateau changed from compressional to extensional and many workers indicate this corresponds closely to the time when maximum elevation was obtained in the region (Cook and Royden, 2008; Molnar et al., 1993).

In southern Tibet there is also abundant evidence for an earlier phase of extension but in a N–S direction. This extension resulted in the formation of a major set of E–W striking, north-dipping normal faults and shear zones known as the Southern Tibetan Detachment System (STDS), which emplaced an overlying mainly unmetamorphosed Tethyan sequence onto metamorphic rocks of the high Himalayas (Burchfiel et al., 1992; Burg and Chen, 1984).

Age constraints indicate that the main phase of the N–S extension took place between 23 and 12 Ma (Coleman and Hodges, 1995; Edwards and Harrison, 1997; Guillot et al., 1994; Murphy and Harrison, 1999; Searle et al., 1997, 1999; Vannay et al., 2004; Viskupic et al., 2005; Walker et al., 1999; Zhang and Guo, 2007). Lee and Whitehouse (2007) propose that N–S mid crustal deformation in the Mabja dome area dated at around 35 Ma is also related to movements on the STDS, but deformation of a similar age in the Changgo area is interpreted by other workers as related to N–S shortening (Larson et al., 2010). The onset of E–W extensional faulting is thought to be between 17 and 7 Ma (Blisniuk et al., 2001; Cottle et al., 2009; Dewane et al., 2006; Edwards and Harrison, 1997; Garzione et al., 2003; Hager et al., 2009; Harrison et al., 1995; Hintersberger et al., 2010; Lee et al., 2011; Murphy et al., 2002; Stockli et al., 2002; Thiede et al., 2006) or even as young as 4 Ma (Mahéo et al., 2007) and significantly younger than movements on the STDS. Distinct kinematics and different age ranges for the two types of extensional structures indicate that they are related to two distinct tectonic events (e.g. Beaumont et

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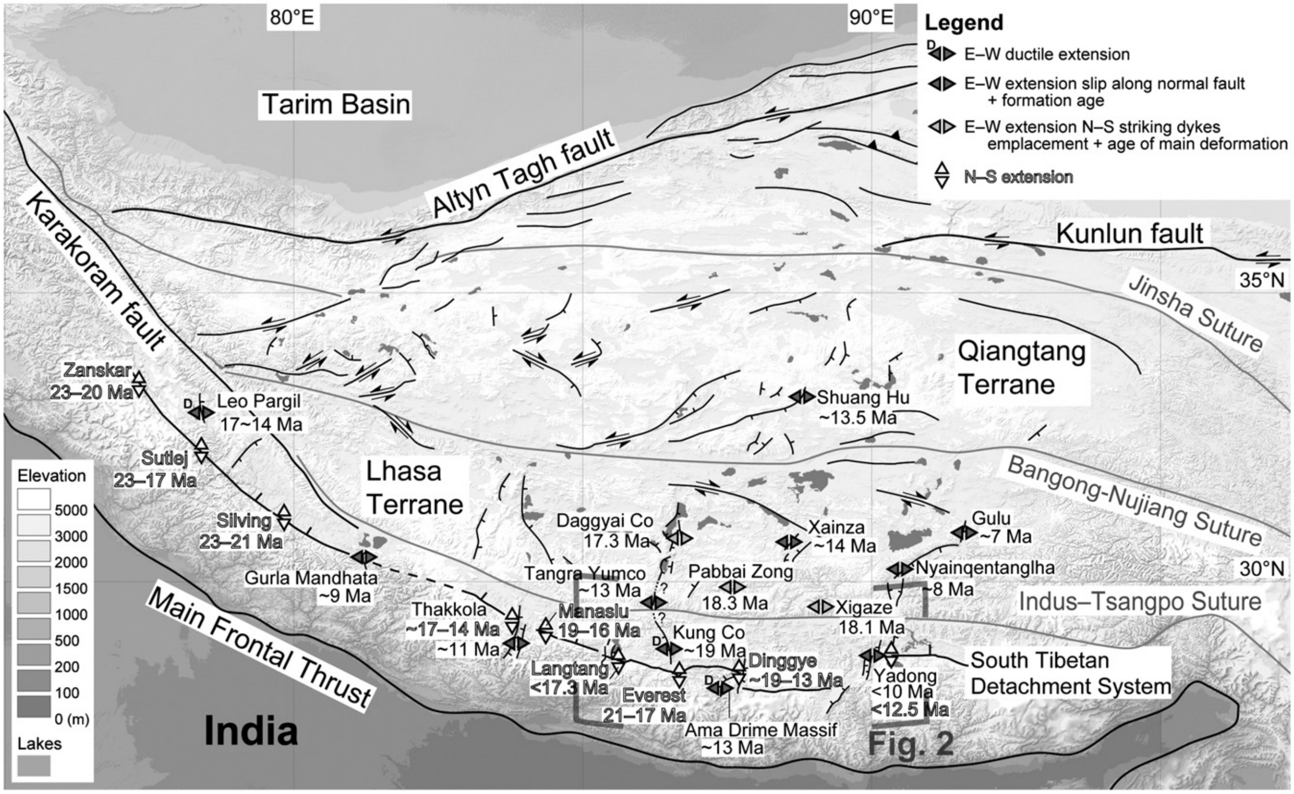

Fig. 1. Digital elevation model (Gtopo 30 data) of the Tibetan Plateau and major active faults. Location of faults modified from Blisniuk et al. (2001) and Taylor et al. (2003). Numbers are estimates of initiation age for E–W extension based on emplacement of N–S striking dykes (light-gray filled double triangles; Williams et al., 2001) and interpreted slip along normal faults (dark-gray filled double triangles), for Leo Pargil (Hintersberger et al., 2010; Thiede et al., 2006), Gurla Mandhata (Murphy et al., 2002), Thakkola (Garzione et al., 2003), Tangra Yumco (Dewane et al., 2006), Ama Drime Massif (Stockli et al., 2002), Xainza (Hager et al., 2009), Shuang Hu (Blisniuk et al., 2001), Yadong (Edwards and Harrison, 1997), Nyainqentanglha (Harrison et al., 1995), Gulu (Stockli et al., 2002), and Kung Co (this study) regions. The white-filled double triangles represent the active age for N–S extension associated with South Tibetan Detachment System for Zanskar (Walker et al., 1999), Sutlej (Vannay et al., 2004), Silving (Searle et al., 1999), Thakkola (Coleman and Hodges, 1995), Manaslu (Guillot et al., 1994), Langtang (Searle et al., 1997), Everest (Murphy and Harrison, 1999; Viskupic et al., 2005), Dinggye (Zhang and Guo, 2007), and Yadong (Edwards and Harrison, 1997) regions.

al., 2004; Blisniuk et al., 2001). There is, however, evidence that the two phases are at least in part contemporaneous. Evidence for relatively young movements on the STDS comes from the Kula granite area. Here that STDS cuts <12.5 Ma granite, so slip in this area is younger than 12.5 Ma (Edwards and Harrison, 1997). These relationships are confirmed by the presence of the ~12 Ma Wagyela granite structurally beneath the STDS which displays a ductile normal slip fabric (Wu et al., 1998). There is also a report of movement on the STDS as young as < 17.2 ka (Hurtado et al., 2001). The presence of ~18 Ma N–S trending dykes provides further evidence for contemporaneous N–S and E–W extension. The age of the dykes partly overlaps with the main documented phase of N–S extension and their orientation suggests that emplacement may be related to the onset of E–W extensional stresses (Williams et al., 2001). These reports indicate that the two stages of extensional deformation may have been contemporaneous and open the possibility that they are related.

In this contribution, we present evidence for ductile E–W extension in the Kung Co area of southern Tibet that took place at ~19 Ma and is associated with a major N–S trending normal fault. This ranks with the oldest previously known examples of E–W extension and is a rare documented example of ductile flow associated with E–W extension. The revised older age for onset of E–W extension is contemporaneous with STDS related N–S ductile extension in the same region. This study reveals a close spatial and temporal association between the two extensional domains, which indicates that they are different manifestations of a single large-scale tectonic event. We discuss the tectonics in the Miocene Himalayas that could have caused development of simultaneous N–S and E–W extension.

2. Geology of Kung Co area

2.1. Regional setting

The southern boundary domain to the Tibetan Plateau is the Himalayas. Within the Himalayan belt several major north-dipping thrust systems can be defined. The most prominent of these are the Main Central Thrust (MCT) and Main Boundary Thrust (MBT). The hanging wall of the MCT consists of the High Himalayan metamorphic sequence, which, in turn, has an upper boundary defined by a major north-dipping normal fault system, the STDS, which can be traced roughly 2000 km along the length of the main Himalayan range (Fig. 2) (Burchfiel et al., 1992). Both the Tethyan Himalayan sequence in the hanging wall of the STDS and the Higher Himalayan Sequence are thought to consist mainly of rocks that make up the pre-collisional Indian continental margin (e.g. Hodges, 2000; Le Fort, 1996).

Numerous granites are exposed in the Tethys Himalaya (Fig. 2) and radiometric dating indicates that they can be divided into an early pre-orogenic group with ages of formation around 560–500 Ma (Lee and Whitehouse, 2007; Lee et al., 2000; Schärer et al., 1986) and a syn-orogenic younger group with ages around 35–10 Ma (Aoya et al., 2005; Kawakami et al., 2007; Larson et al., 2010; Lee and Whitehouse, 2007; Lee et al., 2006; Quigley et al., 2008; Schärer et al., 1986; Zhang et al., 2004a, 2004b). The Kung Co granite intruded around 19 Ma (Lee et al., 2011) and belongs to the younger group. The Kung Co granite is cut by a N–S trending normal fault with a very clear geomorphological expression. This normal fault also cuts