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DISCUSSION

Comment on: "Earthquake geology of Kashmir Basin and its implications for future large earthquakes" by Shah (2013); "Kashmir Basin Fault and its tectonic significance in NW Himalaya, Jammu and Kashmir, India" by Shah (2015)

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Comment

Active faults/out-of-sequence thrusts/tectonic discontinuities have been of great international attention to decipher Himalayan tectonics (Mukherjee et al. 2012; Montomoli et al. 2014; review by Mukherjee 2015). Most of the shortening (Indo-Eurasian convergence) is accommodated in the central part along the Himalayan Frontal Thrust (HFT) system (Wesnousky et al. 1999; Lave and Avouac 2000; Ader et al. 2012), while as in the northwest Himalaya, the strain is differently accommodated across the width of the belt (e.g., Nakata 1989; Yeats et al. 1992; Kaneda et al. 2008; Madden et al. 2011; Ahmad et al. 2013). The distributed deformation has also been observed within the Kashmir basin particularly in the form of several unnamed structures including the Balapur Fault (BF) (e.g., Nakata et al. 1991; Yeats et al. 1992; Kaila et al. 1978; Bhat 1982; Ganju and Khar 1984; Madden et al. 2010, 2011; Ahmad 2010, 2014; Ahmad and Bhat 2012, 2013; Ahmad et al. 2013; Alam et al. 2015a, b), as a result, introducing a new complexity for constraining stress partitioning across the Kashmir Himalaya. The BF is the only established structure in the basin (Ahmad 2010; Ahmad and Bhat 2012, 2013); however, Shah (2013, 2015a) has attempted to rename this well-established structure, i.e., BF as Kashmir Basin Fault (KBF) without any additional structural, kinematic, geologic or geomorphic data in support. Therefore, this comment aims to clarify the confusions created by Shah (2013, 2015a), and it is in this context; we provide a review of the BF.

No active faults/out-of-sequence thrusts/tectonic discontinuities were known north of MBT or MCT in the Kashmir basin, except a few NW–SE suspected fault segments with the collective length of ~45 km along NW Quaternary deposits, mapped from aerial photographs and CORONA satellite images (Nakata et al. 1991), and a south-facing scarp delineated as a possible active fault using Landsat satellite images (Yeats et al. 1992). Subsequent investigations revealed that the southwest-facing scarp (Yeats et al. 1992) is a high-angle thrust fault (reverse) with an average northeast 60° dip and NW–SE strike length of ~40 km (Ahmad 2010; Madden et al. 2010, 2011; Ahmad and Bhat 2012) (Figs. 1, 2, 3). The structure was named as BF because of its exposure on the left bank of Rambiara river (tributary of Jhelum river) at Balapur village (N 33° 75′ E 74° 83′) in Shupiyan district of Jammu and Kashmir state, India (Ahmad 2010; Ahmad and Bhat 2012). With an unknown depth, the BF cuts across (NW–SE) unconsolidated Karewa deposits (Plio-Pleistocene soft sediments), devoid of gouge and breccia; however, rotated gravels at the fault contact have been marked (Ahmad and Bhat 2012). Stratigraphic relations show that the fault has uplifted the Lower Pleistocene Methawoin Member (sand, sandy clay, clay silt and lignite bands) of the Lower Karewa and juxtaposed it to the Middle Pleistocene Shupiyan Member (gravels mostly composed of Panjal Trap fragments of the Upper Karewa (Bhatt 1989). Subsequently, the BF was firmly established by paleoseismic investigation and field data (Madden et al. 2010, 2011; Ahmad et al. 2013; Ahmad 2014). An optically stimulated luminescence (OSL) sample collected from fluvial deposits a few meters above the lower strath gives

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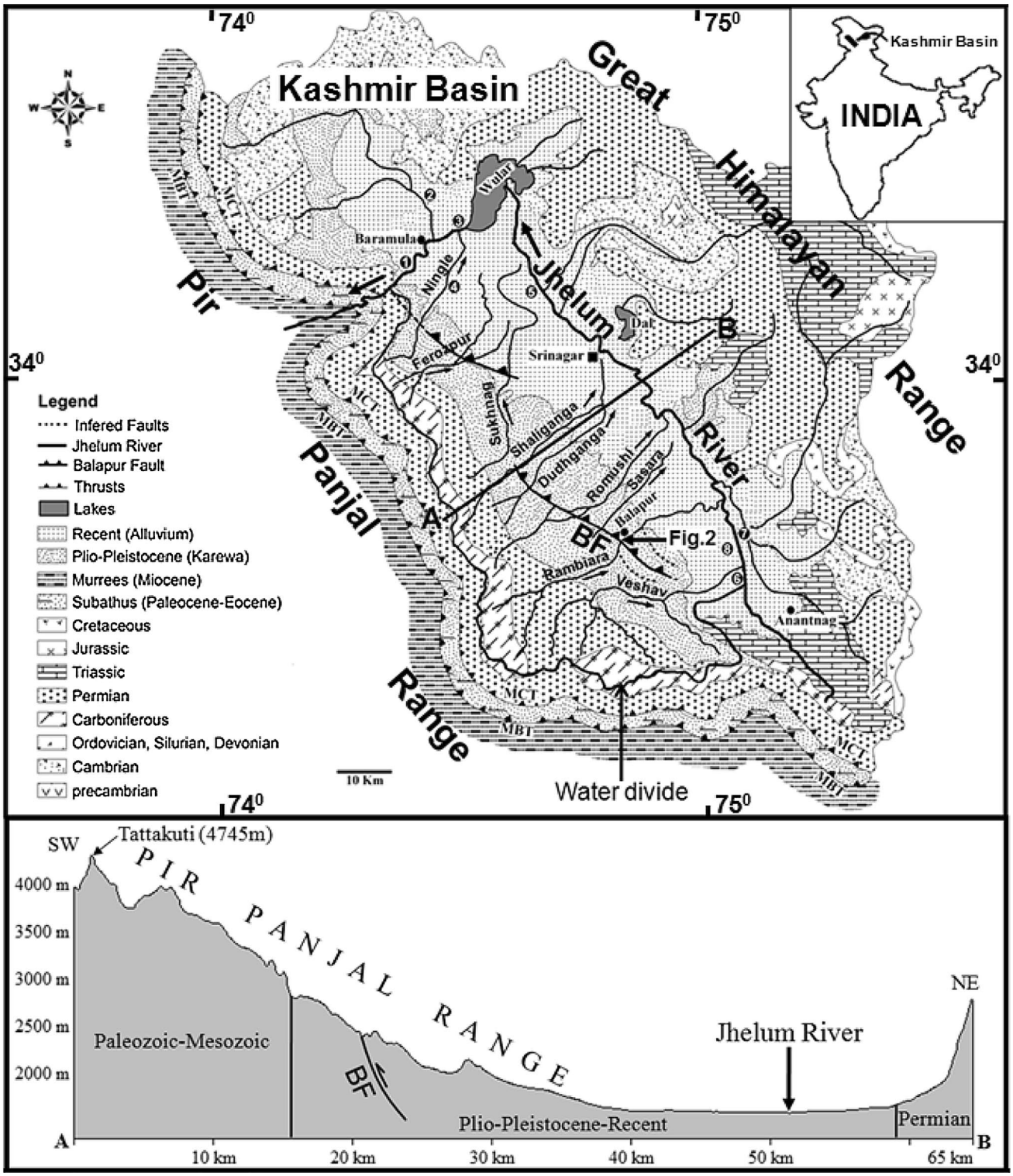

Fig. 1 Geological Formations and structures of Kashmir Himalayas (modified after Middlemiss 1911; Raza et al. 1978; Bhatt 1989; Ahmad 2010, 2014; Ahmad and Bhat 2012; Ahmad et al. 2013) and *A–B* schematic geological cross section and surface topography of the SW Kashmir basin. *MBT* Main Boundary Thrust, *MCT* Main Central Thrust, *BF* Balapur Fault

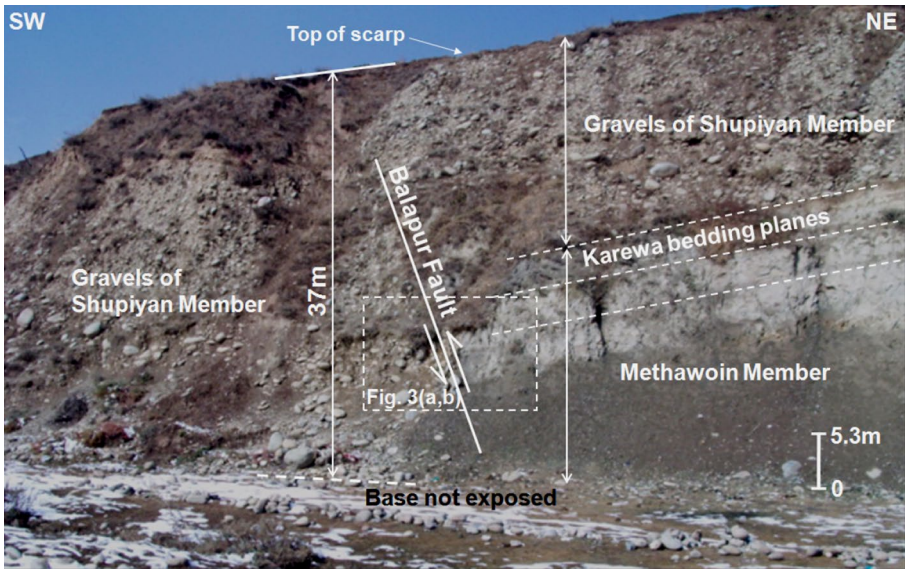

Fig. 2 Photograph of a scarp on the left bank of the Rambiara river, showing the Balapur Fault contact between Methawoin Member (Lower Karewa) and Shupiyan Member (Upper Karewa) at Balapur village (Ahmad et al. 2013)

51 ± 11 ka age and a measured strath elevation above the Rambiara river of 19 ± 1 m at the fault yield a shortening rate of 0.3–1.3 mm/year (Madden et al. 2010). Moreover, paleoseismic trenches across the BF reveal growth strata and colluvial wedges that record at least one earthquake event between 1.5 and 18.7 ka and another between 33.4 and 38.4 ka, with as many as four events in ~40 ka (Madden et al. 2011).

The structure is widely referred as BF in the literature (e.g., Meigs et al. 2010, 2012; Ahmad et al. 2013; Schiffman et al. 2013; Ahmad 2014; Ahmad et al. 2014a, b; Dar et al. 2014; Gavillot 2014; Kundu et al. 2014; Alam et al. 2015a, b), and there is not even a single example where BF has been documented as KBF. Moreover, Shah (2013, 2015a) argues that "a portion of KBF is known as BF"; however, this statement is not supported by a single reference. Shah (2013, 2015a) claimed to identify several northeast-dipping faults (thrusts) in the Kashmir basin using satellite images (90-m resolution Shuttle Radar Topography Mission (SRTM) data, Google maps and Global Multi-Resolution Topography (GMRT)); however, these structures were already delineated as inferred faults (Fig. 4) (Nakata et al. 1991; Yeats et al. 1992; Ahmad 2010, 2014; Madden et al. 2010, 2011; Ahmad and Bhat 2012, 2013; Ahmad et al. 2013). In addition, Shah (2015b) while commenting on Meraj et al. (2015) argued that "a portion of the fault (KBF) runs under Jhelum (Shah 2013)," suggesting that BF is crossing the Jhelum near Baramulla gorge; however, geomorphic signatures do not provide any credence of BF beyond the Jhelum river.

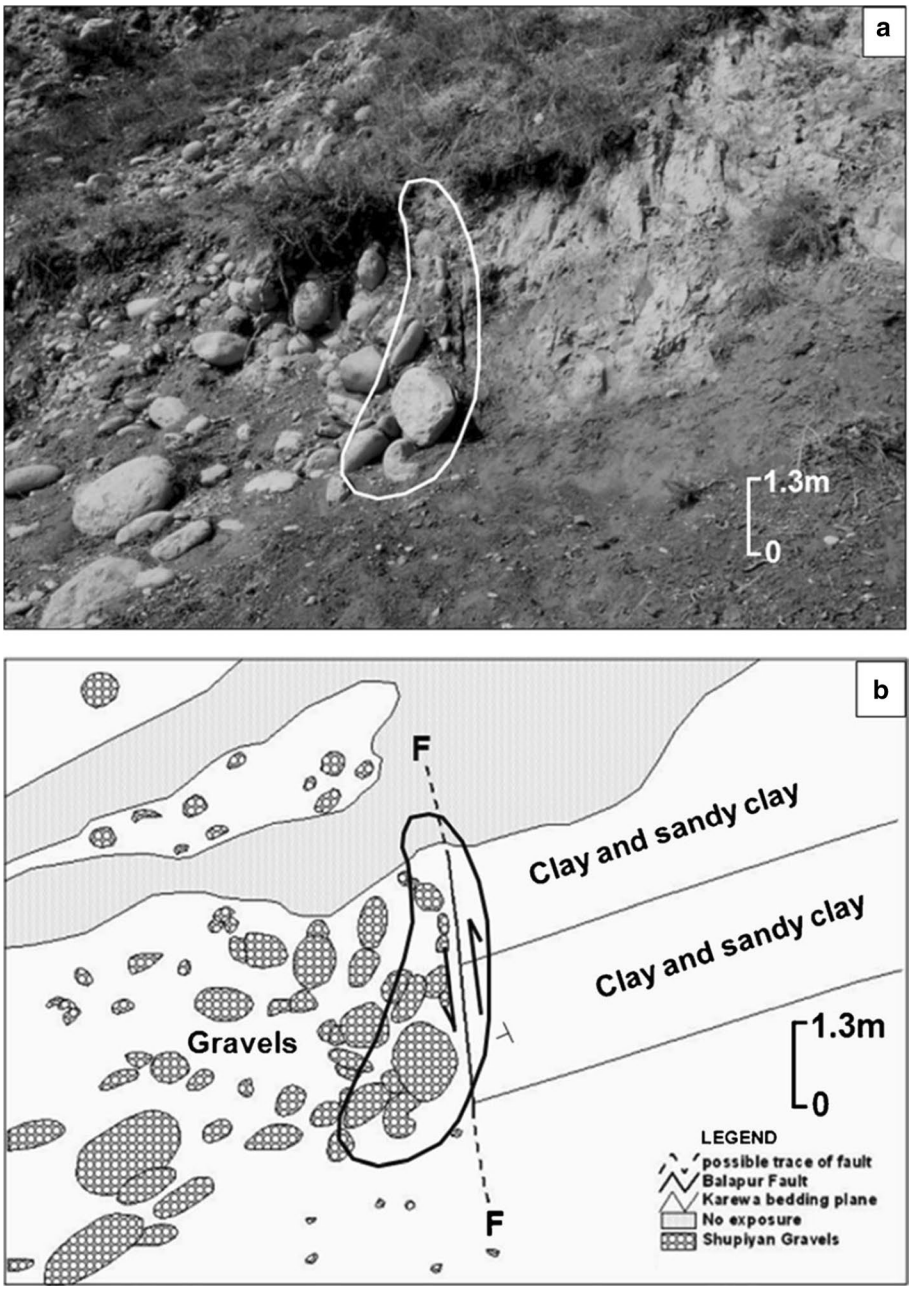

Fig. 3 **a** Photograph shows close contact of gravels (Shupiyan Member) with sandy clay and clay (Methawoin Member) along with rotated gravels due to movement of Balapur Fault encircled with black polygon. **b** Sketch of field relationships (Ahmad et al. 2013)

Based on above discussion and thorough review of geological literature of the Kashmir basin (Godwin-Austen 1859, 1864; Lydekker 1876, 1878, 1883; Oldham 1888; Middlemiss 1896, 1911; De Terra and Paterson 1939; Pascoe 1959; Gansser 1964; Farooqi and Desai 1974; Bhatt 1975, 1989; Fuchs 1975; Wadia 1975; GSI 1977; Raza et al. 1978; Srikantia 1980; Thakur 1981; Bhat 1982; Burbank and Johnson 1982, 1983; Burbank and Raynolds 1988; Krishnan 1982; Singh 1982; Datta 1983; Valdiya 1991; Thakur 1992; Yeats et al. 1992; Agarwal and Agrawal 2005; Basavaiah et al. 2010), we report that "the BF is the only established structure in the Kashmir basin" and "there is no structure called as KBF in the region."

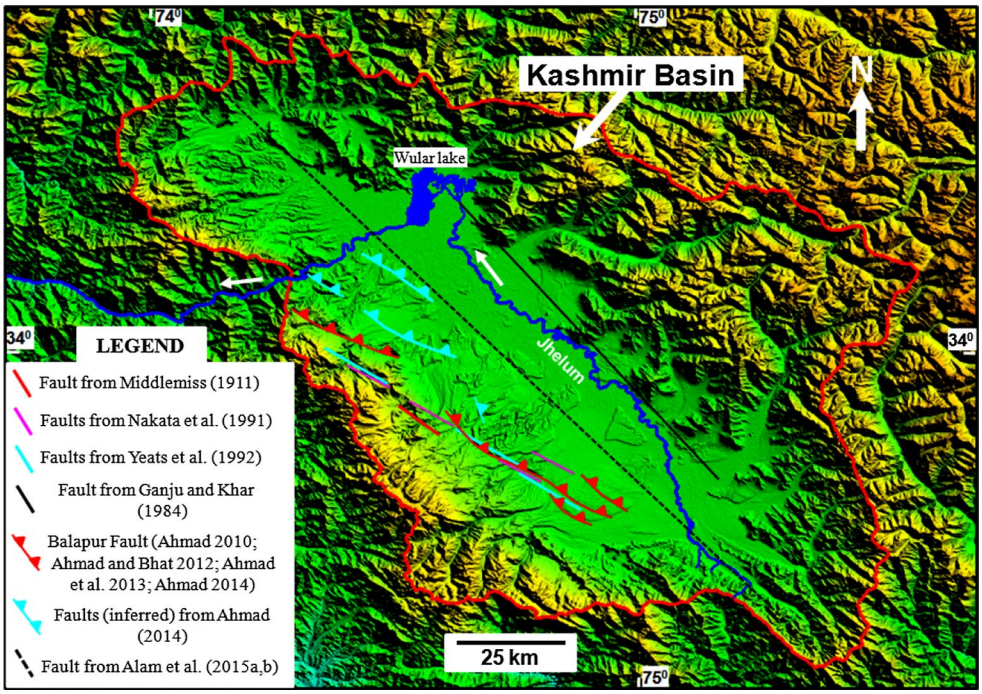

Fig. 4 Fault map of Kashmir basin (Balapur Fault after Ahmad 2010, 2014; Ahmad and Bhat 2012, 2013; Ahmad et al. 2013)

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