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# Triggering of the largest Deccan eruptions by the Chicxulub impact: Comment

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## INTRODUCTION

The environmental crisis responsible for the terminal Cretaceous extinctions has been linked with either episodes of Deccan volcanism or the Chicxulub impact (see Bhandari et al., 1996; Keller et al., 2009; Schulte et al., 2010; Schoene et al., 2015). Richards et al. (2015) proposed a connection between the two events and suggested that there was a change in the Deccan magmatic system as a result of the impact that occurred on the other side of Earth (more than 13,000 km away). They suggested that the seismic waves resulting from the Chicxulub impact could have affected the magmatic system responsible for Deccan volcanism.

The crux of this interesting geophysical model by Richards et al. (2015) lies in the assumptions that (1) the contact between the Lonavala Subgroup (with the Bushe Formation at the top) and Wai Subgroup (with the Poladpur Formation at the base) marks a change in volcanic style and eruptive rates in the Deccan volcanic province, as inferred by Renne et al. (2015), and (2) this change was coeval with the Chicxulub impact. This inference is supported by Richards et al. (2015) on the basis of "a variety of geological and geochemical evidences that appear to be consistent with" (p. 1509) this inferred change. They conclude that this "contact" represents a hiatal disconformity, based on (1) planation surfaces, (2) nonpenetration of structural features from lower (Bushe) flows into upper flows of the Wai Subgroup, and (3) an inferred "flow contact" marked by a "laminated depositional layer of unknown origin" resting over a weathered lava flow of the Bushe Formation.

We argue that the "evidences" of the postulated disconformity are not based on ground truth but are instead convenient interpretations based on superficial and cursory observations.

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## PLANATION SURFACES

The "prominent terraces eroded at the Poladpur-Bushe contact" (p. 1513) identified east of Mahad, "deciphered" by Richards et al. (2015) using Google Earth, are local planation surfaces and have no regional significance at all. Such local planation surfaces are inherent to the step-like topography that gives the Deccan "Traps" its name.

Google Earth views are based on satellite imageries draped over a digital elevation model created using a 30-m-resolution Shuttle Radar Topography Mission (SRTM) data set. Although they are effective visualization tools, they have inherent limitations in terms of accuracy, true ground elevations, and absolute elevation differences. They do not provide a reliable data set on which to base any terrain-related conclusions, unless backed by morphometric and/or field data.

There is a large body of published work (e.g., Dikshit, 1970, 1976, 2001; Subramanyan, 1981; Harbor and Gunnell, 2007; Sheth, 2007; Kale and Shejwalkar, 2008) on the geomorphology of the western parts of the Deccan province that could have been usefully considered by the authors in this discourse. The regional planation surfaces in this region occur at 1200 ± 100 m, 1000 ± 100 m, and 700 ± 100 m above sea level (a.s.l.) in the Deccan Plateau; in the Konkan coastal belt, they are observed at elevations of 750 ± 50 m, 300 ± 50 m, and 100 + 50 m a.s.l. The planation surface recorded in the Varandha Ghat section around Mahad and in the adjoining Savitri River valley is the Lanza-Math surface (named by Karlekar, cited by Bruckner, 2001) at ~100 m a.s.l.; this appears to have been completely missed by the authors.

There is no evidence of any correlation between the chemostratigraphic boundaries and the regional planation surfaces across the Deccan Plateau or the Konkan coastal belt. The present-day topography of the Deccan province is a product of Late Tertiary–Quaternary cyclic landscape evolution (Subramanyan, 1981; Rajaguru and Kale, 1985; Radhakrishna, 1993; Widdowson and Cox, 1996; Sheth, 2007). The current landscape is a manifestation of the modifications of the antecedent drainage under the influence of neotectonic reactivation of ancient zones of weakness in the basement of the Deccan Trap basalts (Peshwa and Kale, 1997; Dole et al., 2002; Kale et al., 2016). The identified planation surface that the authors describe as "conspicuous and extensive set of topographic terraces" (p. 1512 and Fig. 3) is not regional, nor do the authors provide evidence of its having a one-to-one relationship with the Poladpur-Bushe contact. It is at best a local artifact in no way linked to the Poladpur-Bushe contact (which does not occur at this elevation at all!). There is no physical evidence to support the speculation of the terraces representing exhumed landforms created during the break in eruptive history between the Bushe and Poladpur Formations.

## STRUCTURAL FEATURES

The lack of penetration of fractures and faults in the upper flows (of Poladpur and Ambenali Formation from the Wai Subgroup) and their prevalence in the lower flows (of Bushe Formation (from the Lonavala Subgroup) are used by Richards et al. (2015) to suggest that there was a time gap between the eruption of the Lonavala Subgroup and the Wai Subgroup. Studies on the fracture patterns in the Deccan Traps across the Western Ghats and in the Narmada Valley (Peshwa et al., 1987; Rajurkar et al., 1990; Narula et al., 2000; Geological Survey of India, 2001) have shown that fracture zones of tectonic origin can be traced across multiple flows upward from base to the top. The vertical and lateral continuity of tectonic fractures

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is well established all along the Western Ghats Escarpment, irrespective of the chemostratigraphic affinity of the basaltic flows. Only joints developed during the cooling of the lava or produced due to weathering are limited to individual flow units.

The manifestations of the fracture zone differ in the different types of basalts transected by them. In the compact basalts, the fractures are manifested as sharp continuous joints. In vesicular basalts, the fractures tend to be diffused into a set of small subparallel joints, with an inverse relation between the vesicularity of the basalt and the linear continuity of the fractures, making them appear diffuse or discontinuous. Consequently, even within a single flow, the continuity of a fracture may be perceived to be interrupted. It is the rheology and competency of the basalt that influence the vertical penetration and/or continuation of fractures, rather than chemical type (Kale et al., 2014, 2016).

Fracture-trace analysis has established that the fracture systems in the Deccan Province are the surface manifestations of channelized reactivation of basement shears during Late Tertiary and Quaternary times (Peshwa and Kale, 1997; Misra et al., 2014). In the area east of Mahad, a strong N-S (to NNE-SSW) extensional fracture system, coupled with weaker E-W and NW-SE sets of shear fractures, is recorded in these studies. However, none of them is interrupted at the formation contact in the Ghat section east of Mahad, as depicted by Richards et al. (2015). Their vertical and lateral continuity from the lower Bushe flows to the upper Poladpur and the overlying Ambenali flows can be demonstrated across the intervening Poladpur flows.

In the Deccan Traps, it is difficult to demonstrate the sense or magnitude of "dislocation" across a fracture plane given that the material on both sides of the plane is similar—nearly identical. Unless clear evidence of dislocation can be provided, it is advocated that the term "fracture zone" be used rather than "fault" (sensu stricto), as has been done by most of the publications on the structural characteristics of the Deccan Traps (Peshwa et al., 1987; Rajurkar et al., 1990; Narula et al., 2000; Geological Survey of India, 2001). We therefore question the term "fault" used in the paper and the consequent implications drawn by the authors.

## CONTACT BETWEEN THE BUSHE AND POLADPUR FORMATIONS

The southern edge of the map by Beane et al. (1986) is ~20 km north of this section, but it has been used to justify the identification of the Bushe-Poladpur contact by Richards et al. (2015, their Fig. 3) at an elevation of ~260 m a.s.l. This contact has been mapped (Subbarao and Hooper, 1988; Khadri et al., 1999) in the Varandha Ghat section at around 120 ± 10 m a.s.l. This leaves a discrepancy of ~150 m between the actual contact and the postulated contact.

The photograph highlighting the contact (Richards et al., 2015, their Fig. 3A) is neither an interflow contact nor a tuffaceous horizon; it represents a part of the weathered portion of a thick compound pahoehoe flow. The upper and lower contacts of this compound flow with the overlying and underlying flows occur at ~310 m a.s.l. and ~214 m a.s.l., respectively. Both of these contacts display unambiguous interflow horizons capping flow-top breccias. The entire flow in question is a part of the Poladpur Formation (see Subbarao and Hooper, 1988). This particular "gray horizon" is neither a flow contact nor an interflow horizon. It is a weathering artifact of an artificially sculpted road cutting, yielding it a "laminated appearance."

## CONCLUDING REMARKS

The "geochemical evidence" mentioned by Richards et al. (2015, p. 1512) is an overview of earlier works that is interpreted to show changes in the geochemical characters across the Poladpur-Bushe contact. They proceed to endorse this with "evidence for a stratigraphic time break, or disconformity…." (p. 1512) We encourage the authors to examine the credibility of the conjectural conclusions used as "evidence" in support of the postulated break between the Wai and Lonavala Subgroups and the implications on their model.

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