Comments on Kumar et al. (2023), Evidence of Strain Accumulation and Coupling Variation in the Himachal Region of NW Himalaya From Short Term Geodetic Measurements. Tectonics https://doi.org/10.1029/2022TC007690.

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Kumar et al. (2023) in their article discuss and highlight the complexities involved in the comparison of long-term and short-term ongoing deformation in the Northwest Himalaya and their influence over the topographic evolution of the region. Their observations that rely largely on the GNSS geodetic results (Kumar et al., 2023) have also been the basis of conclusions presented in a companion paper by Malik et al., 2023a. The conclusions presented in the latter-mentioned paper have been questioned in a rejoinder by Singh and Rajendran (2023) and defended by Malik et al. (2023b). Below we present pointwise inconsistencies in the present study (Kumar et al., 2023) and the conclusions presented therein. We present our differing observations of the two segments of the fault system called the 'Khetpurali-Taksal' Fault (KTF-1 and KTF-2), as discussed in the paper by Kumar et al. (2023):

A. KTF-1

1) According to Kumar et al. (2023), the KTF-1 trending almost N-S direction accommodates a mean dextral slip of ~4.6-5.7 mm/yr. This mean slip rate is interpreted to be an outcome of GNSS geodetic vector resolution from an arc-parallel slip of ~ 4-5 mm/yr. However, purely based on the information provided by Kumar et al. (2023) as shown in Figure 1a (reproduced here from Kumar et al., 2023), the realization of the vectors on the KTF-1 appears to be incorrect, from our perspective, as shown in Figure 1b. The correct resolution shows that the arc-parallel convergence of 4-5 mm/yr can only be resolved as a sinistral (left-lateral) slip on the KTF-1 (see Fig. 1b, as shown here).

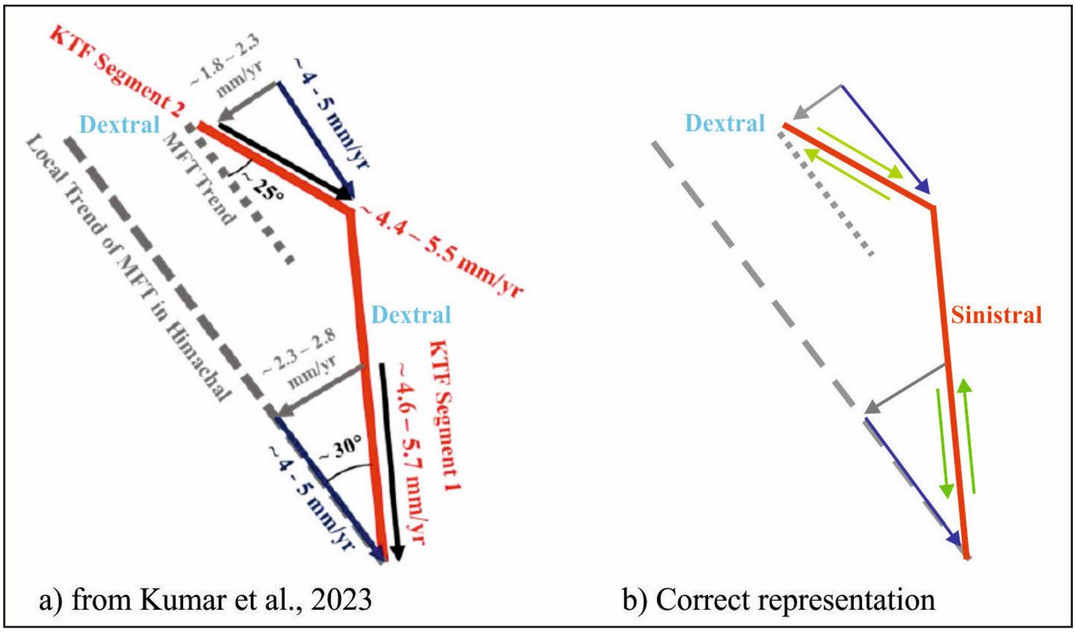

Figure 1: Vector resolution of GNSS data. a) from Kumar et al., 2023; b) Vector resolution as interpreted in this study.

2) Moreover, there is attendant evidence where the so-called KTF-1 breaks the MFT (corresponding to the Sabilpur Fault), which includes offsets preserved in geological sections, offsets on the MFT and the topography offset all of which exhibit a left-lateral sense (Nanda, 1981; Kumar and Tandon, 1985; Jukar et al., 2019; Gill et al., 2021; Kumar et al., 2022; Singh and Rajendran, 2023).
3) Further, the GNSS geodetic network of Kumar et al. (2023) is not dense enough around the KTF-1 segment to clarify the sense of motion on this structure. In fact, there are no stations around the KTF-1 in a few tens of kilometers (Figure 2). Further, by the authors' own admission (Kumar et al., 2023), the four sites (CHPU, SOLN, SANR, SHLS) closest to the KTF-1 segment are malfunctioning and therefore the authors decided not to use the unreliable data from these sites in subsequent analysis. In fact, one of the GNSS sites CHPU is located within a strongly deforming piedmont zone (Kim et al., 2023; Sahadevan and Pandey, 2023). Therefore, in view of the quality of the datasets and site conditions, it is felt that Kumar et al. (2023) could provide no clarity on the sense of movement, and ambiguity about the nature of slip/offset on the KTF-1 remains, both in the long-term and short-term.

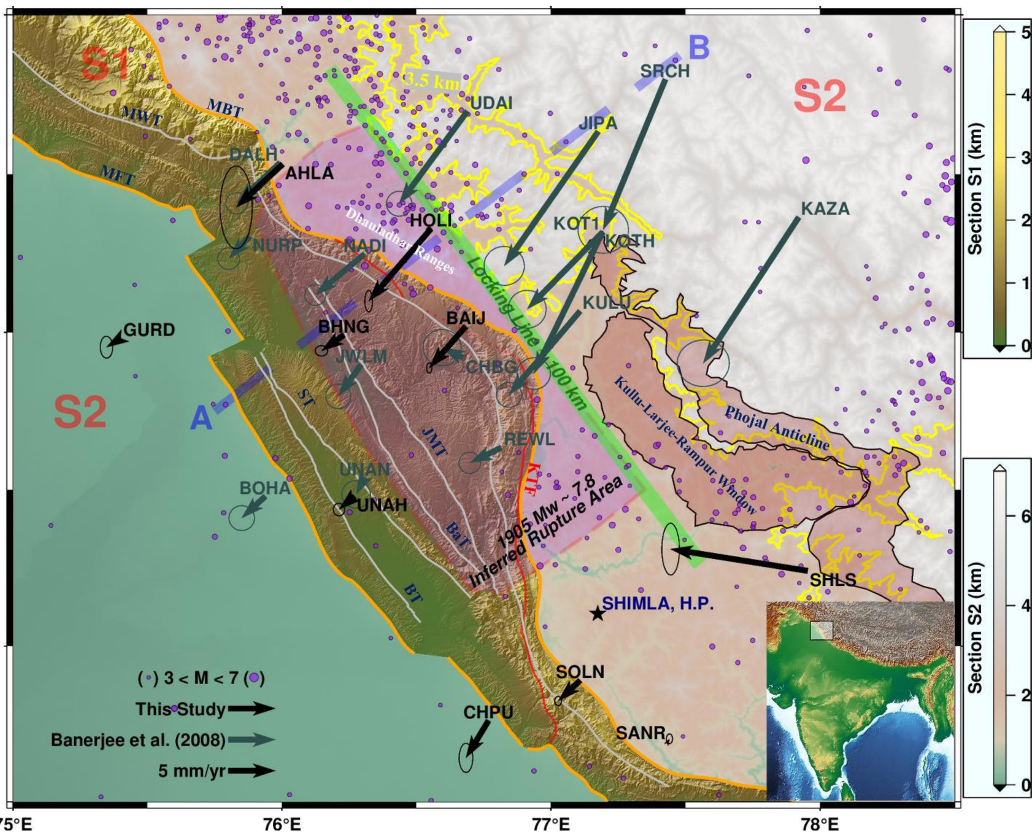

Figure 2: Distribution of the GNSS network around the KTF (Kumar et al., 2023).

4) Most striking is that the data presented for the western and eastern profiles by Kumar et al. (2023) are all entirely located to the west of the KTF-1 (Figure 3). There is absolutely no spatial correspondence or data density on the east of KTF-1 to allow any assertions about the segment boundary at KTF-1. The Eastern Profile (EP) corresponds with the central part of the Kangra Reentrant (KR) whereas the Western Profile (WP) is marginally in the Reentrant.

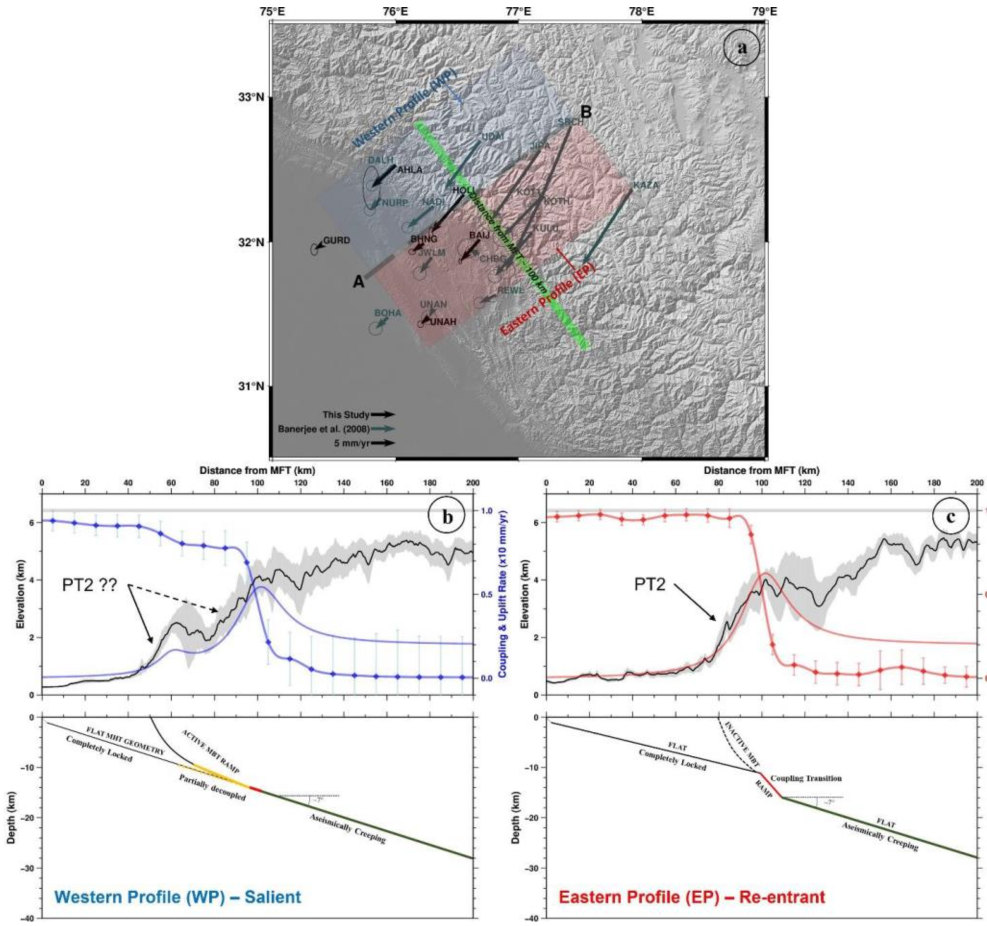

Figure 3: Figure from Kumar et al. (2023) to show location and data from Western Profile (WP) and Eastern Profile (EP).

5) The authors (Kumar et al., 2023) at several places make statements about the Salient to the west of Kangra Reentrant, which corresponds with their Western Profile (WP). Refer to the following examples cited from their paper and ***highlighted***:

   a) ***Section 4: Variation in the arc-normal interseismic coupling across the Kangra re-entrant and the western adjoining salient***

   b) *Section 4: The eastern profile (EP) includes the GPS velocities encompassing the region where the Kangra re-entrant exhibits maximum width, and* ***the western profile (WP) includes the GPS velocities where the re-entrant transitions into salient****. This 2-D investigation approach allowed for unique well-constrained solutions throughout the two profiles and enabled us to make a relative assessment of the inter-seismic coupling variations and locking behaviour in the transition zone on the portion of MHT lying underneath the Kangra re-entrant and the* ***western adjoining salient*** *similar to the analyses of Marechal et al. (2016) in Bhutan Himalaya and Lindsey et al. (2018) in Nepal Himalaya*

   c) *Section 4.2: The entire ~100 km stretch of the Kangra re-entrant (Profile-EP) shows near-perfect coupling (coupling ratio ~ 0.9-1.0), while further north it drops rapidly to near zero exhibiting almost perfect binary coupling transition (Fig 3c).* ***The western transects (Profile WP)*** *show a distinct pattern of variation in the coupling ratio (Fig 3b).*

It should be noted that 5 a, b and c demonstrate that the Eastern Profile is across the Kangra Reentrant (KR) to the west of the KTF-1 and the WP is further west of it. The Salient referred by Kumar et al. (2023) is not the Nahan Salient (NS) which is located on the east of KR (Figure 4). NS also lies across to the east of the postulated KTF-1 of Kumar et al. The segment boundary between Kangra Reentrant and the Nahan Salient is already known prior to Kumar et al. (2023), although with different degrees of uncertainty depending upon the data used (Virdi, 1979; Singh et al., 2012; Hetényi et al., 2016; Nennewitz et al., 2018; Thakur et al., 2019; Hubbard et al., 2021). So while asserting KTF-1 to be a segment boundary, it would have been appropriate to bring in the Nahan Salient and the Ropar-Manali lineament/fault for the arguments/discussions (Figure 4, 5). Ignoring the important segment of Nahan Salient, due to either lack of consistent evidence or inadequate data does not support the inference of KTF-1 being an important segment boundary.

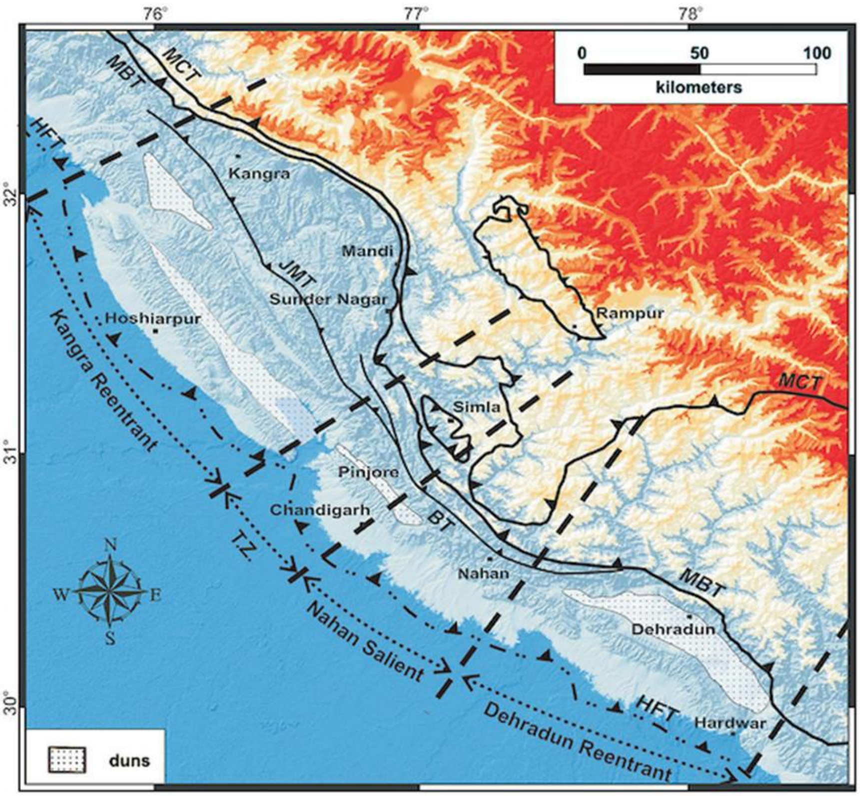

Figure 4: Sinuous trace of MBT in the NW Himalaya defines the structural segments of Kangra Reentrant (KR), Nahan Salient (NS) and Dehradun Reentrant (DR). TZ is the Transition Zone between Kangra Reentrant and Nahan Salient (from Singh et al., 2012).

Furthermore, judging the data representation regarding the western and eastern profiles (WP and EP), as presented in Kumar et al. (2023), there is a void insofar as data from east of the KTF-1 is concerned. The lack of data makes it difficult to conduct a proper interpretation of the fault kinematics so as to characterize it as a segment boundary. Moreover, there is a large divergence between the boundary/lineament/fault as proposed by other authors (Virdi, 1979; Singh et al., 2012; Hetényi et al., 2016; Nennewitz et al., 2018; Thakur et al., 2019; Hubbard et al., 2021) and KTF-1 which is not clarified.

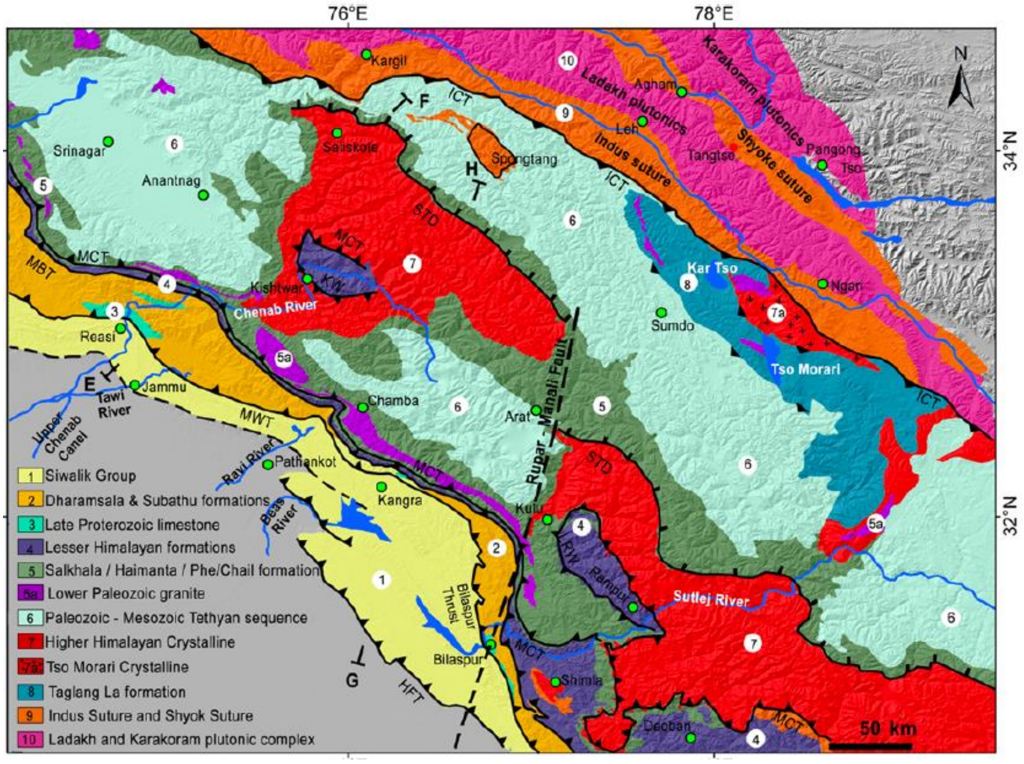

Figure 5: The location of the Ropar-Manali Lineament/Fault (from Thakur et al., 2019) closely corresponds to the KTF-1 in the Dharamsala and Subathu Formation (2) and deviates eastward, further south of it.

6) According to Kumar et al. (2023), *the study region lies approximately west of the recently proposed fault segment boundary defined by the ~N-S trending Khetpurali-Taksal Fault (KTF) (Figure 1) that separates the NW segment (Himachal) of the coupled MHT from the Central segment (Kumaun-Garhwal). This region is marked by the observation of significant arc-parallel deformation and variations in the strain accommodation and slip partitioning behaviour across it (Malik et al., 2023). It has been suggested that the KTF most possibly accommodated a significant slip during the 1905 ~Mw7.8 Kangra earthquake in the Himachal region, which partially ruptured the MHT (Malik et al., 2023).*

The authors assume that the KTF-1 acts as a fault segment boundary separating the NW (Himachal) segment of the seismogenic MHT, currently locked, from the Central (Kumaun-Garhwal) segment and accommodates most of the ongoing arc-parallel convergence in the region. However, there is no study yet to ascertain the slip rate along the KTF-1. Moreover, the author's assumption ignores a large structural/seismic segment of Nahan Salient between the Kangra Reentrant and the Dehradun Reentrant (Singh et al., 2012; Gahalaut and Arora, 2012) which represents the NW segment (Himachal) and the Central segment (Kumaun-Garhwal), respectively of Kumar et al. (2023). Therefore, based on the presented datasets of Kumar et al. (2023) it will be extremely flawed to assume that KTF-1 is a segment boundary between the NW segment (Himachal) and the Central segment (Kumaun-Garhwal), ignoring the Nahan Salient. Moreover, the contradictory results on the kinematics of KTF-1 are not argued to a reasonable level to justify the segment boundary. Overall the identity and role of KTF-1 away from the RML/Fault is neither justified/clarified to an acceptable level nor there is enough data presented to clarify/justify it as the segment boundary. Any further hypothesis or modelling scenario based on such data and results appears to be a long shot without an adequate basis.

It comes out that Kumar et al. (2023) present conflicting observations on the KTF-1 segment:

1) The boundary corresponds to a part of the already identified RML/Fault that is dextral (Thakur et al., 2019). However, towards the south, their KTF-1 deviates eastward from this to offset the MFT near Sabilpur. There is overwhelming geological and geomorphic evidence to show that the Sabilpur Active Fault (SAF) has a left-lateral sense of movement (Nanda, 1981; Kumar and Tandon, 1985; Jukar et al., 2019; Gill et al., 2021; Kumar et al., 2022; Singh and Rajendran, 2022). So, the article is unable to address the different kinematics of KTF-1 over its length (whether dextral/sinistral or both, then how?).
2) Our corrected vector resolution on their KTF-1 (like what (Kumar et al. 2023) have done on KTF-2) brings out a different result from their data i.e., KTF-1 is a sinistral fault (Figure 1a&b). This is the reverse of their own assumption whereas they show a dextral fault at KTF-1.
3) Their KTF-1 corresponds to the RML/Fault in the central part (Virdi, 1979) which is already known to be a segment boundary (Singh et al., 2012; Hetényi et al., 2016; Nennewitz et al., 2018; Thakur et al., 2019; Hubbard et al., 2021). In its southern part, the KTF-1 deviates from this RML/Fault towards a sinistral segment near Sabilpur offsetting the MFT (Singh and Rajendran, 2023). Therefore, in view of the large number of published works, their poor data quality, and the lack of spatial correspondence of their original WP and EP with the KTF-1 around their segment boundary, the KTF-1 seems to be misplaced as a segment boundary both in terms of its spatial position and kinematics.

B. KTF-2

The KTF-2 corresponds to the Kangra Valley Fault of Malik et al. (2015) and there are already concerns about the role of KTF-2 in strain partitioning. Szeliga and Bilham (2017) and Paul et al. (2018) note that orogen parallel displacements along individual structures may not contribute significantly to strain partitioning and so the KTF-2 may accommodate a minor component of tectonic strain. According to Paul et al. (2018), “the 1905 Kangra earthquake might not have occurred on the KVF, nonetheless, the KVF is identified as an active 60-km strike-slip fault known to have slipped post-1620 (Malik et al., 2015). Additionally, at least three moderate earthquakes in the years 1968, 1978, and 1986 occurred at a depth range of ~10–15 km in the Kangra Valley (Kumar & Mahajan, 2001) and they showed prominent strike-slip components to dip-slip along the MHT.” Therefore, all the available data indicate minor strike-slip reorganization in the Kangra Reentrant (Paul et al., 2018), which may be secondary in nature and not primary surface ruptures as claimed by Malik et al. (2015).

C. KTF-1 and KTF-2

Concerning the two faults, i.e. the KTF-1 and the KTF-2, firstly there are inconsistencies in the data and results presented for the two faults with opposite kinematics (Fig. 1). And whether the two faults join together to serve as a segment boundary, as claimed by Kumar et al, (2023). As per the presented datasets and all other existing datasets, there seems to be no clear picture coming out from Kumar et al., 2023. Moreover, the actual geodetic data pertains to WP and EP from the Kangra Reentrant, both of which lie to the west of KTF-1. Therefore any inferences drawn on the KTF-1 should ideally include data from the east of KTF-1, as well, i.e. from the area around Nahan Salient.

D. Declaration: The authors declare that the content in the manuscript is either previously published or our own inferences. All the previously published data/figures/tables have been properly cited in the text and listed in the reference section below.

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