Earth Surface Dynamics

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Title: Palaeo-landslide dams controlled the formation of Late Quaternary terraces in Diexi, the upper Minjiang River, eastern Tibetan Plateau

Dear Editor and Reviewers,

We would like to express our heartfelt appreciation for your valuable and insightful comments on our manuscript. Your expertise and guidance have significantly contributed to the improvement of our work. We are grateful for the time and effort you dedicated to reviewing our research thoroughly. Your suggestions and constructive criticism have played a crucial role in enhancing our study's clarity and overall quality. We sincerely appreciate your valuable input, which has undoubtedly strengthened our manuscript. Thank you once again for your invaluable contribution.

Please find the detailed response in the attached document.

Best regards,

Xuanmei Fan on behalf of all co-authors

The Response to Comments from Anonymous Reviewer

Specific Comments
Comment 1 Some words and phrases are mislead readers.
Response 1 Thank you for your help in modifying the words and sentences in the manuscript. I have modified them according to your suggestions, as follows: (1) L13-15: In this paper, we investigated the geomorphology, sedimentology, *and chronology of the terraces at the Tuanjie village (seven staircases) and at the Taiping village (three staircases) in the Diex area*. (2) L20, L310, L315: *Late Pleistocene*. (3) L23-25: Our analysis, combined with the tectonic uplift rate, river incision rate, and high-resolution climate data, indicates that the blockage and collapse of the palaeo-dam have been a significant factor in the formation of *the river terraces in the* tectonically active mountainous *region*. (4) L63-64: This indicates that the Diexi palaeo-dammed lake has experienced *more than* one outburst flood event. (5) L67-69: Due to the lack of sedimentary sequence and chronological data, *further study on the evolution of palaeo-dam and the causes of terrace formation is needed*. (6) L112-115: *The seven terrace staircases are located in Tuanjie village* (32º2′ N, 103º40′ E) are located in Tuanjie village, on the right bank of the Minjiang River, at the mouth of the Songpinggou tributary (Fig. 1c). *The three terrace staircases are in Taiping village* (32º12′13″ N, 103º45′53″ E), at the mouth of Luobogou Gully, which is 12 km upstream of the Tuanjie (Fig. 1d) (Fan et al., 2021; Wang et al., 2005). (7) L225-226: Tunajie *Terraces have* seven staircases, Taiping *Terraces have* three staircases, all of which are based on lacustrine deposits (Fig. 4). (8) L277-278: The sedimentary sequences of Terraces T1 and T2 are comparable to T5 and T6 of the Tuanjie *site* (Fig. 5). (9) L263: Angular *phyllite fragments* occur in T3. (10) L512-513: The repetitive long-term wave erosion, fluctuating along the palaeo-lake *beach*,

resulted in the beveling and backwearing of T2 (Malatesta et al., 2021).

(11) L567: Before 32 ka, a palaeo-dam blocked the river, with its *crest* reaching 2500 m.

Comment 2

L82: Width of what? stream itself, or valley bottom, or valley at some level above the stream. It should be specified.

Response 2

Thanks for your comments. We checked it, and rewrote it on *L82*, as follows:

The width *of the valley bottom* varies from 60 to 300 m.

Comment 3

L102: Sediments at the river bed are not Triassic, regardless of what was the source rock.

Response 3

Thanks for your comment. We modified it on *L102,* as follows:

Large amounts of *Quaternary* sediments are deposited along the Songpinggou river bed.

Comment 4

L106-107: Unclear. If cumulative evaporation exceeds cumulative precipitation, where the water in the river comes from?

Response 4

Thanks for your constructive comments.

The values of the annual cumulative evaporation, and the average temperature and precipitation are for the Diexi area. Diexi area has dry climate and little rainfall, and the precipitation is the lowest in the upper reaches of Minjiang River (Yang, 2005). So, the water of the river comes from the upstream.

We modified it on *L105,* as follows:

In Diexi area, with the strong effect of the prevailing winds, the annual cumulative evaporation can reach 1000-1800 mm (Yang, 2005), and the average temperature and precipitation are 13.4℃ and 500-600 mm, respectively.

Comment 5

L196&198: which one? There are 3 terraces.

Response 5

Thanks for your comment. We modified it on *L196-199,* as follows:

The AMS ^{14}C sample collected from the *highest lacustrine deposits* of the Taiping *village* was used for comparison with the OSL sample (TP19-1), which was taken from the same position. The AMS ^{14}C sample collected from the *highest lacustrine deposits* of the Tuanjie *village* was compared with the AMS ^{14}C dating of the *highest lacustrine deposits* of the Taiping *village*.
Comment 6 L260-261: Not very clear what the term "strength" means here.
Response 6 Thanks for your comment. We modified it on *L260-261,* as follows: These features suggest that the gravel units of T2 and T3 are clast-rich debris flows with high strength *energy* or pseudoplastic debris flows with low strength *energy*.
Comment 7 Line 290: blocking events that occurred upstream or downstream?
Response 7 Thanks for your comments. We modified it on *L290-291,* as follows: Furthermore, the two mud-phyllite clasts layers in Taiping T3, indicate that *two blocking events occurred downstream*.
Comment 8 L318: Generally, paleosol, as well as modern soil is not deposited - it evolves on the already existing substrate (see section 22A.3.2.8 of McCalpin's Paleoseismology.)
Response 8 Thanks for your comments. We modified it on *L317,* as follows: The ages of the paleosol of each terrace differ, but most paleosol units were *developed* during the Holocene.
Comment 9 L323-324: To my knowledge there landforms were mainly not deposited but eroded in lake sediments. Only thin gravel layers aere deposited over them.
Response 9 Thanks for your comments. We modified it on *L323,* as follows: All the terraces were *formed* during the Holocene.

Comment 10

L342: Unclear how gravel units overlying lake sediments in which terraces had been eroded could be older than lacustrine silt.

Response 10

Thanks for your valuable comments. We rewrote it on *L341-342,* as follows:

Comparing all the ages within the Tuanjie Terraces, the gravel units *of T2 and T5* have older ages *than the lacustrine deposits of T2 and T5, respectively* (Fig. 5).

Comment 11

L360: Add the level (altitude) range of these terraces above the riverbed.

Response 11

Thanks for your valuable comments. We added the height above the river for each terrace age sample in the Supplementary. But unfortunately, not all samples have this data, we use '-' to represent no data.

Comment 12

L361-362: Unclear. It seems that you mix number of terraces and number of sites.

Response 12

Thanks for your comments. Sorry, I mixed the concepts of terrace and site. We rewrote it on *L360-363,* as follows:

Along the upper Minjiang River, there are a minimum of *fifteen terraces*, with *nine* terraces located upstream of the Diexi area (from Zhangla to Gonggaling), *two terraces* near the Diexi area *(Taiping, and Tuanjie)*, and *four terraces* are developed downstream (from Maoxian-Wenchuan).

Comment 13

L360-384: I think some comment will be useful how terraces described here are related with terraces eroded in the sediments accumulated in the Paleo-lake.

Response 13

Thanks for your valuable comments.

The formation of terraces is mainly caused by tectonic activity and climate change (Pan et al., 2003; Singh et al., 2017; Do Prado et al., 2022; Avsin et al., 2019; Gao et al., 2020), both of which have a wide range of influence. Therefore, it is necessary to describe and summarise the dating results of terraces in the upper reaches of the Minjiang River. The formation mechanism of the Diexi study area

and its upper and lower terraces is distinguished to indicate the particularity of the formation mechanism of Diexi terraces.

We rewrote it on *L376-386,* as follows:

The terraces in the area stretching from the Zhangla basin to the source of the Minjiang River are attributed to tectonic uplift (Yang et al., 2003; Yang, 2005; Yang et al., 2011; Yang et al., 2008; Chen and Li, 2014; Zhu, 2014). *Although Diexi and Zhangla are located on the Minjiang fault, in* the Diexi area, the formation and evolution of the Tuanjie and Taiping Terraces *are different, they* were influenced by the evolution of a palaeo-dam (Duan et al., 2002; Wang et al., 2005; Wang, 2009; Zhu, 2014). The *downstream* terraces in the Maoxian-Wenchuan region share similar features with the terraces in Diexi, as they are also believed to have formed as a result of the outburst of a palaeo-dammed lake (Zhu, 2014). *However, the downstream terraces are located in the Maoxian-Wenchuan fault, which makes it different from the Diexi terraces in the formation process. All these indicate that the formation and evolution of Diexi terraces are independent of the upstream and downstream terraces.* In the following sections, we will present additional evidence to explore this phenomenon further.

Comment 14

L417-418: Lake and dam boundary cannot be deposited. Needs rewriting.

Response 14

Thanks for your valuable comments. We rewrote it on *L419-420,* as follows:

The *dating results of the boundary of palaeo-lake* and palaeo-dam in Xiaoguanzi *supported the palaeo-lake* was *formed in* 34.87±0.76 and 35.54±0.83 cal. ka BP.

Comment 15

L432-433: Unclear. Landslide had to cause lake formation first. Downstream of what?

Response 15

Thanks for your valuable comments. We rewrote it on *L433-434,* as follows:

Besides, the palaeo-landslide in Manaoding occurred at 16.75±0.62 cal. ka BP (Wang et al., 2012), suggesting that *the second outburst event happened around 17 ka*.

Comment 16

L463-464: Rate during what period

Response 16

Thanks for your comments. We mentioned in the first sentence:

During the damming period of the Diexi palaeo-dammed lake (32-10 ka), the incision rates in these three sections ranged from 8.3-85.3 mm/yr, 13.6-198 mm/yr, and 58 mm/yr, respectively, from upstream to downstream (Table. S2).

Comment 17

L476-477: But it overlaps with the period of 30-15ka

Response 17

Thanks for your valuable comments. We rewrote it on *L476-477,* as follows:

Later on, during the period of 30-*10* ka, Diexi experienced *more than* ten distinguishable climatic and environmental *stages, alternating between cold and warm* (Wang et al., 2014; Wang, 2009).

Comment 18

L480: is it correct to differentiate climate in so closely located areas?

Response 18

Thanks for your comments.

Firstly, the upper reaches of the Minjiang River are located in the transition zone from the Tibetan Plateau to the Sichuan Basin. The terrain is complex and the elevation between the upper and lower reaches is very large, resulting in significant climatic differences within the region. The instrument records that the precipitation in Diexi area is less than that the upstream and downstram regions, which indicates the particularity of Diexi area. Secondly, Zhangla basin also developed terraces, we therefore find it necessary to mention the palaeoclimatic information of both places.

Comment 19

L481: of what? unclear

Response 19

Thanks for your comments. We rewrote it on *L481,* as follows:

The chronological results *of the Tuanjie and Taiping terraces* range from 32.40±2.07 ka to 3.78±0.18 ka. We compared our dating ages with the variations in the climate curves (Fig. 7).

Comment 20

L485-486: Please clarify - are these gravels interbeded in lake sediments or were deposited on the

terraces eroded in lake silt? If the latter - how can it be?

Response 20

Thanks for your comments.

Yes, these gravels were deposited on the lacustrine deposits. As we saw in the field (Figs. 2, 3).

We were also shocked to have such a sedimentary sequence. After we obtained the dating results and investigated the sedimentological and geomorphological characteristics of the Diexi area, also the downstream of the palaeo-dam, we concluded that the gravels were deposited during the palaeo-lake damming period. The upstream materials input and eroded the lacustrine deposits, formed a channel and deposited gravels.

We rewrote it on *L486-488,* as follows:

The two gravel units *(Tuanjie T2 and T5)* are older than the lacustrine deposits of the terraces in which they are *covered*, indicating that the input of materials from the upper reaches of the Minjiang River did not cease during the blockage of the palaeo-dam, resulting in the accumulation of such a thick unit of gravels.

Comment 21

L496: or glaciers melt?

Response 21

Thank you for your reminding. Around 20,000 years ago, Diexi area may have been induced to experience large-scale hillside instability, due to the melting of glaciers in the Last Glacial Period (Wang et al., 2012). Therefore, the warming climate is leading to the overtopping of the dam, and these bodies of water may have come from melting glaciers upstream.

So, we rewrote this sentence on *L497-498*, as follows:

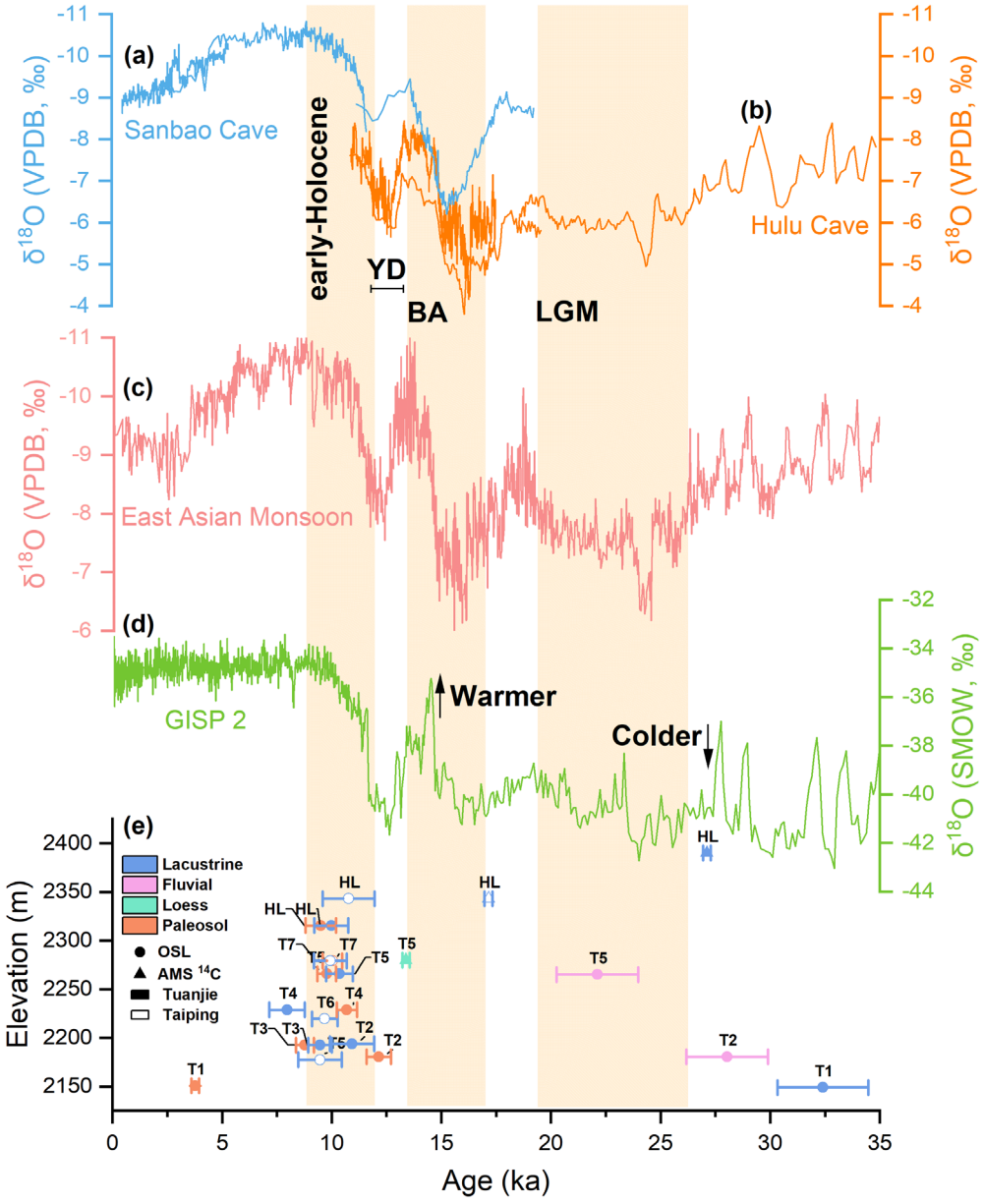
Although the dam-break events became more frequent during the early Holocene, it is challenging to confirm whether warmer periods triggered increased rainfall *or glacier melt*, leading to the overtopping of the dam, *its breach* and the formation of terraces.

Comment 22

For Figure. 7, it will be useful to specify what marks are from the Tuanjie and what from the Taiping sites.

Response 22

Thanks for your valuable comments. We redrew the Figure 7e with solid symbols to represent Tuanjie samples and hollow symbols to represent Taiping samples.



Comment 23

L526-527: deposition cannot form a channel/ Erosion forms a channel.

Response 23

Thanks for your comments. We rewrote it on *L528,* as follows:

Gravity and density cause the material to be deposited in the Diexi palaeo-dammed lake, *which erodes to form* a channel.

Comment 24

L529: I think it requires some comment. Why first outburst did not evolve continuously causing complete breach. And why paleo-lake could exist for so long time? The dam was inevitably overtopped and water had to frow over it for millennia.

Response 24

Thanks for your comments.

Firstly, the elevation, sedimentary stratigraphic characteristics and dating results have confirmed that the Tuanjie and Taiping terraces correspond to each other (Section 5.3). Then, the evolution process of the palaeo-dam needs to consider the Taiping terraces' sedimentary characteristics and age results. Therefore, we cannot ignore the age results of the highest lacustrine deposits of the Taiping village, which are 17.15 cal. ka and 10.77 ka, respectively (Fig. 5b). It has the same elevation (2390 m) as the highest lacustrine deposits of the Tuanjie village, but there is a 10,000-year difference.

During 27-17 ka, there was no event in the study area, and the palaeo-dam was relatively stable. Therefore, we believe the river was blocked again during 27-17 ka, causing the lake surface to expand to the Taiping village.

Secondly, it can be seen from the chronological test results of the terraces at all levels of Tuanjie and Taiping that do not present a sequence of 'from highest to lowest terraces, the ages changed from older to younger', which does not support the first outburst evolving continuously, causing the complete breach.

This paragraph mainly explains how the damming and outburst events impact upstream and downstream areas. The formation and outburst of the palaeo-dam are summarised in Section 5.4.

Comment 25

For Fig. 9, I would suggest to add one more stage - when the paleo-lake had been silted completely and fluvial deposition took place leading to gravels over lacustrine silt.

Response 25

Thanks for your comments. We added a new stage and a profile in Fig. 9, and rewrote the figure name, as follows:

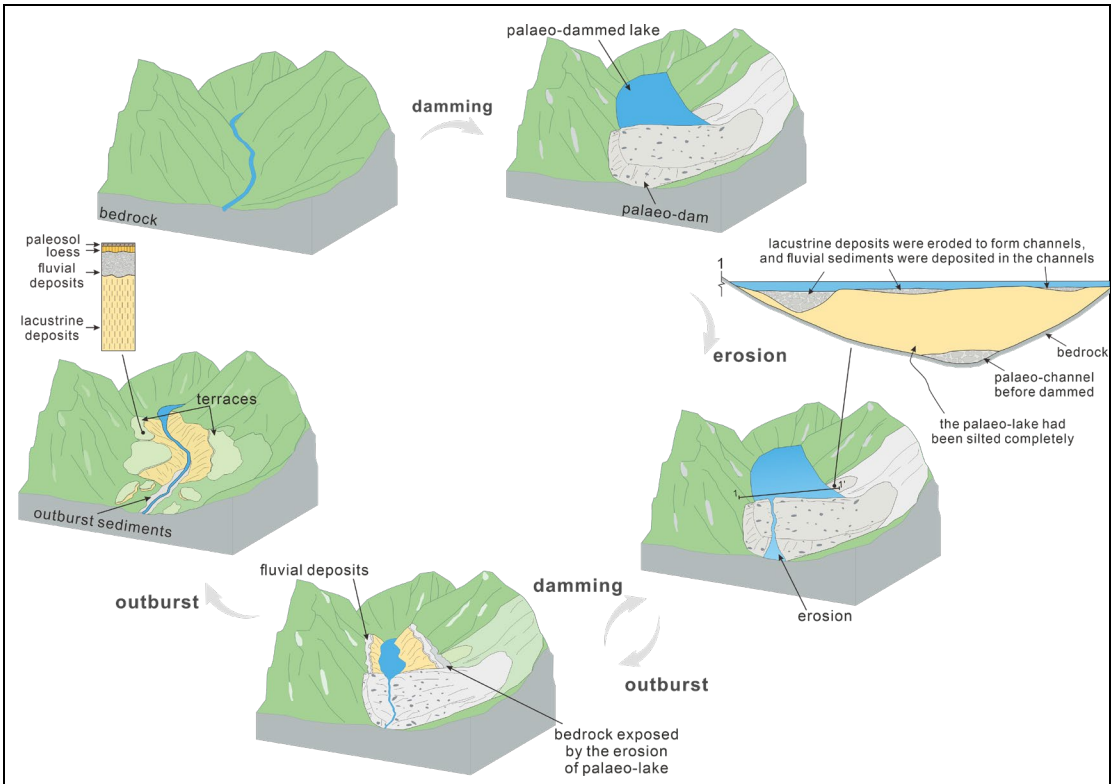


Figure 9. Model of palaeo-landslide dam driven valley landscape and terrace evolution. The palaeo-landslide blocked the river and formed a palaeo-dam, the water level rose and formed a palaeo-dammed lake. *Lacustrine deposits were eroded to form channels, and fluvial sediments were deposited in the channels. The water overflowed the palaeo-dam.* During the outburst period, the palaeo-dammed lake shrank, the lacustrine and fluvial deposits were exposed, and the palaeo-dam was cut down to form a river channel. Subsequently, through repeated damming and outbursts, the palaeo-dam completely collapsed and deposited as outburst sediments, and terraces were formed along the river. The stratigraphical sequence of the terrace is lacustrine deposits, fluvial deposits, loess, and paleosol, from bottom to top.

Comment 26

L568: which one?

Response 26

Thanks for your comments. We rewrote it on *L570,* as follows:

During this period, the lake shore receded until the *highest lacustrine deposits of the* Taiping *village* (Fig. 10c).

Comment 27

For Fig. 10, Do I understand correctly that T2 formed at stage b was buried and then exhumed again?

Looks very strange.
Response 27 Thanks for your comments. Yes, T2 formed in Phase b. Under the continuous erosion of fluvial sediments, channels were eventually formed in lacustrine deposits, and gravels were deposited. Subsequent lacustrine sediments were covered, but loose lacustrine sediments are difficult to deposit during subsequent evolution.

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