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,

We would like to extend our deepest gratitude for your invaluable feedback and suggestions on our manuscript. Your expertise and thoughtful insights have made a significant impact on the refinement of our work. We truly appreciate the time and effort you dedicated to thoroughly reviewing our research and providing detailed comments. Your constructive criticism has been instrumental in enhancing the clarity, coherence, and overall quality of our manuscript. Your input has undoubtedly elevated the scholarly value of our study. We are sincerely grateful for your invaluable contribution, which has greatly enriched our research. Thank you once again for your invaluable support and guidance.

Please find the detailed response in the attached document.

Best regards,

Xuanmei Fan on behalf of all co-authors

The Response to Comments from Editor

Specific Comments
Comment 1 Language and style: There are many instances of unclear language throughout the manuscript. I recommend a thorough proofreading and editing process to improve the clarity and coherence of the writing. This includes the use of terminology (for example, see my minor comment on the term disaster below) and the use of precise language and statements (for example, why is data incomplete and why does it make studies exploratory in Line 53). The meaning of sentences like "terraces in the Diexi area are typical fluvial terraces in the upper Minjian River") are difficult to grasp for readers that are not familiar with the study area. Also, it is unclear what "the systematic study ... is incomplete" (L61) actually means. Later, you state that "climate change can affect the topgraphy of terrace staircases" (L516). I don't know how that would work unless climate change modulates geomorphic processes that ultimately lead to incision or aggradation, both of which are processes that form terraces and which are controlled by upstream processes of sediment production and downstream changes of baselevel. These are just a few examples for many instances of unclear language that pervade the current version of the manuscript.
Response 1 Thanks for your comments. We proofread and edited the manuscript for clarity and coherence. For example: L53: *The upper Minjiang, for instance, displays many terrace sequences with origins that remain debated (Yang, 2005). But due to the lack of detailed sedimentological, chronological and geomorphological information, the role of extreme geomorphic events, such as landslides and outburst floods, are still being explored (Yang et al., 2003; Yang, 2005; Gao and Li, 2006; Zhu, 2014; Luo et al., 2019).* L61: *The Diexi terraces (Fig. 1) have been examined by previous workers (Wang et al., 2005; Yang et al., 2008; Fan et al., 2019), but a systematic analysis has yet to be conducted.* L516: This section already modified as: *(1) A fluctuating climate may be seen in terrace geometry. In papers by Mao (2011), Jiang et al. (2014), and Shi (2020), it is argued that Tuanjie T2 displays an*

irregular sequence of ages with depth that suggest repeated fluctuations in the lake level by up to 11 m between 19 and 11 ka (Table S2). Regarding Tuanjie T1, we note the extraordinary terrace width. Following the model described by Malatesta et al. (2021), we suggest that repetitive wave erosion associated with the fluctuating lake shoreline resulted in the bevelling and back-wearing at T1, creating a very wide terrace (Fig. 8). We note some additional erosion may have occurred owing to the positioning of the Tuanjie terraces on the concave margin of the valley (Fig. 1b) where lateral fluvial erosion tends to be accentuated.

Comment 2

Research objectives: I like how you state the objectives of your study in the last paragraph of the introduction. Yet, these objectives should be described in a more concise and specific way. You write that the "purpose of this paper are". Rather, you should state the objectives of your study. Then, you write that the objective is "(1) to clarify the deposition ages and sedimentary characteristics". Here, you must be more concise in describing, what you actually do, which is offering/complementing new geochronological and sedimentological constraints/evidence. Objective 2, "to reveal the blockage and outburst of the palaeo-dam" is unclear as a study objective. It rather sounds like you are offering already here an explanation for the phenomen, which you are actually going to study. Objective 3, "to explore the influences of tectonics, climate, ..." is rather an overall aim of your study, but not an immediate objective. It will be good to make a clear distinction between research objectives and the overall aim of the study. This will also allow you to generalize the relevance of your findings to answer a broader research question.

Response 2

Thanks for your comments. We rewrote these sentences on *L63-68* as follows:

Here, we seek to address the unresolved questions of the origins of the Diexi terraces, including the following aims: (1) to conduct a detailed analysis of terrace sedimentology; (2) to obtain absolute depositional ages of the terraces (at Tuanjie and Taiping); and (3) to understand the evolution of the Diexi palaeo-dam since its formation at more than 35 ka (Wang etal., 2020). Our broader objective is to provide a better understanding terrace formation linked to extreme geomorphic events in mountain

regions.

Comment 3

Discussion and interpretation: The discussion of the dating results seems to me overtly optimistic concerning the precision and accuracy of the OSL ages. Moreover, the interpretation misses out processes that may affect the OSL results. For example, is it possible that OSL ages are overestimated due to incomplete bleaching which is a common problem in extreme sediment transport events (de Boer et al., 2024) and high-turbidity flows (Mey et al., 2023)? Could insufficient bleaching be an explanation why dated gravel deposits are embedded between sediments with younger ages (Fig. 5)? What about the factors contributing to the reservoir effect (L353)? Are they actually relevant in the study area (e.g. upstream carbonatic rocks, evidence for subaqueous landslides, etc.?).I have also concerns about the interpretation of beveling and backwearing of terraces by lake level variations. Can there be sufficient wave action in such a lake to suffiently erode the lake shores? What about fluvial phases during which lateral erosion dominates. Wouldn't that be much more effective in eroding the terraces? Also stating that tectonic activity is not a critical factor in the evolution of Tuanjie and Taiping terraces is highly misleading (L478). Isn't tectonic activity required to actually drive high denudation rates, landslides and the formation of landslide dams, and to lead to high erosion rates upstream? Is it possible that the three processes, extreme sediment transport events, climate, and tectonics are all important, but that they just act on different time scales and with varying stochasticity?

Response 3

Thank you for your comments, and sharing these two papers that have expanded my understanding of the effects of extreme sediment transport events and high turbulence on OSL ages.

Our OSL is taken from (1) lacustrine sediments, which were deposited in stable depositional environments. These samples have a certain distance from the overlying gravel unit and are not affected by the deposition of these gravels. (2) gravel units, two samples were taken from the gravel units of T5 and T2 respectively. The sedimentary facies analysis shows that they were deposited in low energy environments rather than extreme events and high turbulence. (3) paleosol unit, also not

associated with any catastrophic event.

Based on the above points and our test results, we believe that bleaching is sufficient.

There are three factors that contribute to the reservoir effect, we rewrote these three points as follows:

(1) the lower ^{14}C-activity carbon and the atmosphere-water exchange (Deevey et al., 1954; Keaveney and Reimer, 2012; Ascough et al., 2016); (2) landslides, debris flows, or other disturbances causing surface sediments to drop into the lake, mixing older sediments with new (Counts et al., 2015; Shi, 2020); and (3) the re-deposition of older organic components, such as stored charcoal (Kaplan et al., 2002; Krivonogov et al., 2016).

As you mentioned, lateral erosion of the fluvial phase is effective in forming the wide surfaces of Tuanjie T1. Thanks for your reminding, this manuscript lacks this consideration. We rewrote on *L356-348* as follows:

We note some additional erosion may have occurred owing to the positioning of the Tuanjie terraces on the concave margin of the valley (Fig. 1b) where lateral fluvial erosion tends to be accentuated.

Tectonic activity, climate changes and extreme events all great influence on the formation and evolution of terraces. According to our analysis in sections 5.4.1 and 5.4.2, tectonic activity and climate changes were not the main factors that dominated the formation and evolution of the terraces. Therefore, to clarify, we rewrote these two sections 5.4.1 and 5.4.2 as follows:

5.4.1 Effects of tectonism on the Diexi terraces

The Tuanjie and Taping terrace sites are sufficiently close (12 km) to be considered subject to the equivalent tectonic forcing. In Section 5.2, we divided the upper Minjiang River into three segments: Gonggaling to Zhangla (upstream of Diexi), the Diexi area, and the Maoxian-Wenchuan area (downstream of Diexi). Since the initial damming at the Diexi palaeo-landslide, the fluvial incision rates in these three segments of the upper Minjiang is measured at 8.3–85.3 mm/yr, 13.6–198 mm/yr, and 58 mm/yr, respectively (see Table S2). In comparison, the Minshan Block (which includes the reach from Gonggaling to Maoxian) is thought to have experienced an average uplift rate of 1.5 mm/yr during the Quaternary (Zhou et al., 2000). Clearly, recent incision rates in the Diexi area have been several-times faster than the average uplift rate of the Minshan Block. This highlights the unique character of Diexi and suggests that tectonic activity is not a primary factor in the formation of the terraces.

5.4.2 Effects of climate changes on the Diexi terraces

The regional climate has undergone three transitions from cold-dry to warm-humid climate between ~ 40 and 30 ka (Zhang et al., 2009) followed by more than ten alternations of cold to warm between 30 and 10 ka (Wang, 2009; Wang et al., 2014). The terraces at Tuanjie and Taiping span the past 32 ka, so to investigate the influence of climate we examine the climate variations over the same period (Fig. 7). The four climate proxies reveal significant fluctuations from the end of the Last Glacial Maximum (LGM) to the early Holocene followed by relative stability throughout the Holocene.

It is tempting to speculate that warmer periods triggered wetter conditions or glacier melt leading to the overtopping of the palaeo-dam and formation of terraces; however, we cannot see any clear relationship between the age of the terraces and the climatic variations over the past 35,000 yrs (Fig. 7). Nevertheless, two important points are worth making:

(1) A fluctuating climate may be seen in terrace geometry. In papers by Mao (2011), Jiang et al. (2014), and Shi (2020), it is argued that Tuanjie T2 displays an irregular sequence of ages with depth that suggest repeated fluctuations in the lake level by up to 11 m between 19 and 11 ka (Table S2). Regarding Tuanjie T1, we note the extraordinary terrace width. Following the model described by Malatesta et al. (2021), we suggest that repetitive wave erosion associated with the fluctuating lake shoreline resulted in the bevelling and back-wearing at T1, creating a very wide terrace (Fig. 8). We note some additional erosion may have occurred owing to the positioning of the Tuanjie terraces on the concave margin of the valley (Fig. 1b) where lateral fluvial erosion tends to be accentuated.

(2) Some degree of climate control can be recognised in terms of the aeolian and weathering processes. The loess unit at Tuanjie T4 (~13.4 ± 0.1 cal. ka BP) dates to just before the Younger Dryas reflecting a cool depositional environment; loess observed at Tuanjie T3 and T2, as well as Taiping T3 and T2 suggest ages slightly younger. Most of the palaeosol units relate to the warming conditions of the early Holocene.

(3) The three outburst floods (~ 27 ka, ~ 17 ka and ~ 12 ka, reported at Section 5.5) in Diexi area were only happened in the climate fluctuation periods. We speculated these floods may be the result of the glacial melting. As Wang et al. (2012) mentioned that during the Last Glacial Period, the melting of glaciers triggered massive hillslopes instability, and formed palaeo-dammed lakes.

(4) The absent of outburst flood in the Holocene may be related to the warm and stable climate.

Comment 4 L42: The term disaster is usually used if a natural event causes wide-spread damages and loss of life. We don't know much about the impact of Quaternary extreme events on humans. Thus, instead of using the term disaster, please use the term extreme events as used in the context of magnitude-frequency relations).
Response 4 Thanks for your comments. We used the "*extreme events*" and "*extreme geomorphic events*" instead of "disaster".
Comment 5 Comment 3: It is unclear to what kind of deposits you are referring to here. If sediments are deposited along the (active) river bed, they are most likely very recent as the river bed is a product of erosion, transport and deposition of recent material. Terraces straddling the river can be of a specific age, e.g. Triassic or Quaternary. Also the underlying rocks can be of some specified age. As you write it, its rather unclear, what you mean.
Response 5 Thanks for your comments. Through our rearrangement, this description is not the area that we discussed in the manuscript. We deleted it.
Comment 6 Comment 4: Is the Diexi Valley (105) the same as Diexi area (106)? If yes, please stay consistent with geographical names.
Response 6 Yes, the Diexi Valley is the same as Diexi area. We used "*Diexi area*" in the manuscript.
Comment 7 Line 116: Please be consistent in the precision at which you report coordinates. Here, you report seconds, which are most likely not required whereas in line 113 you report only degree minutes.
Response 7 Thanks for your comments. We deleted the seconds.

Comment 8 In Line 117, you write "The course of the river is a deep canyon". Please rewrite, for example, that the river has carved a deep canyon. Maybe also state how deep the canyon is. Try to make quantitative statements where possible.
Response 8 Thanks for your comments. We deleted this sentence, as we described on *L81-83* as: *The Minjiang valley widens downstream, overall, varying from 60 to 300 m wide at the valley floor (Yang, 2005; Jiang et al., 2016; Ma, 2017; Zhang, 2019), and up to 3000 m deep flanked by steep hillslopes that are typically 30-35° (Zhang et al., 2011; Guo, 2018).*
Comment 9 Comment 14: Please be more precise what you have dated here. As the reviewer said, the lake boundary (shore?) cannot be deposited, and hence it cannot be dated. What did you date here? Shoreline ridges? If not, are you actually dating sediments derived from litoral processes?
Response 9 Thanks for your comments. To clarify the second and third points, we modified it on *L374-377,* as follows: *(2) at Xiaoguanzi, lacustrine sediments dated to 34.9 ± 0.8 and 35.6 ± 0.8 cal. ka BP (Wang et al., 2012) are observed capping part of the palaeo-landslide dam; and (3) the same occurs at Manaoding dated to 34.5 ± 0.2 cal. ka BP (Wang et al., 2012).*

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