This paper explores the formation of cirque glaciers in glaciated terrains, typically forming in bowl-shaped depressions with flat floors and steep headwalls, primarily originating from the accumulation of snow and ice avalanching from upslope areas. The authors apply this concept to identify similar cirques on Mars, suggesting that cirques deepen through wet-based glacial erosion. Their detailed morphometric analysis is commendable, particularly in relating gullies with cirques, aligning with the proposal that gully heads serve as initiation points for cirques on Earth. However, there is one major point that requires clarification to enhance the paper's clarity.

We thank the reviewer for their comments on the connection between gullies and cirque-like alcoves. We agree with the reviewer that the manuscript would benefit from further clarity in areas. We outline these changes below.

In lines 314-317, the authors reference works by Costard et al. (2002), Williams et al. (2008, 2009), and Dickson et al. (2023b), suggesting that gully formation on Mars may be driven by meltwater resulting from increased insolation during high obliquity excursions. Later, in lines 450-452, they propose that gully incision might also be influenced by CO_2 or dry mass wasting. It is unclear which gully formation mechanism the authors prefer in their work to relate to the formation of cirque-like alcoves. Can gullies formed by CO_2 ice sublimation or dry mass wasting be considered initiation points for cirque-like alcoves, or is this specific to gullies formed by meltwater generation linked to higher obliquity excursions?

The model for gullies to act as initiation points for cirque-like alcoves is not related to whether the gullies formed by CO_2 ice sublimation, dry mass wasting, or meltwater generation. Cirque glaciers on Earth require some kind of topographic depression to form, possibly at the initial depth of 50-100 m (e.g., Barr et al., 2019). Cirque-like alcoves on Mars likely require an initial hollow to form, though the exact mechanism of how the hollow or gully formed does not matter. We mention gullies as one example, where the gullies could act as cold traps for snow (e.g., Dickson et al., 2023) to accumulate into glaciers.

We edited these lines in Section 5.1.2 to read as follows:

"To explain the southward bias of cirque-like alcoves, we propose that this is consistent with periods of higher obliquity >45° on Mars, when poleward facing slopes received higher insolation and summer day temperatures (Costard et al., 2002) and equator facing slopes received less insolation. As a result, southward facing alcoves in the northern mid-latitudes were more favorable for ice accumulation during periods of high obliquity. Similarly, for regions poleward of 40° like Deuteronilus Mensae, gullies were primarily observed on on equator-facing slopes (Harrison et al., 2015; Conway et al., 2018), possibly due to the melting of ground ice during periods of high obliquity (Costard et al., 2022), though the exact formation mechanism of gullies remains unclear (e.g., Conway et al., 2019; Dundas et al.. 2022). Regardless of how gullies are initiated, they may act as a local depression in a location where water-ice precipitation could later accumulate for cirque-like alcove formation, such as if the gullies acted as a cold trap for snow (e.g., Dickson et al., 2023). For example, gullies could provide the initial concavity for a later cirque-like alcove to develop when glaciation occurs (Section 5.2.2), which is consistent with gully heads that have been proposed as initiation points for cirques on Earth (Derbyshire and Evans; 1976). However, in the case of meltwater, we note that cirque-like alcoves may prefer to reside on equator-facing slopes because this would allow for increased insolation and the chance for meltwater as temperatures increase (e.g., Pilorget and Forget; 2016; Dundas et al., 2022; Dickson et al., 2023b). We explore this potential association between gullies and cirque-like alcoves further in Section 5.2.2."

See response below to the comment "*Currently, the concepts appear mixed…"* for the edited text in Section 5.2.2 to address the reviewer's comments.

This distinction is crucial if the authors use it to link the early stages of cirque-like alcoves to gully activity, explaining the southward bias in the aspect of cirque-like alcoves, and gully heads as initiation points for cirque-like alcoves. The authors must address the two distinct thoughts on gully formation on Mars: one linking gully formation to meltwater and the other proposing a dry origin. For the sake of clarity and the readers' understanding, the authors should make this part clear in the paper.

One reason that the dry mass wasting origin has been deemed unlikely is because the mean gradient of gullies is lower than the angle of repose of dry material on Mars (e.g., Noblet et al. 2024). The exact mechanism that formed the gullies is not necessarily (and on Earth typically not expected to be) the same way that the cirque-like alcoves formed. We added the following sentence to reflect this in the manuscript: "We suggest that the notches are gullies and may act as initiation points for cirque-like alcoves, though the formation of cirque-like alcoves are not determined by whether the gullies formed by CO2 ice sublimation, dry mass wasting, or meltwater generation."

Currently, the concepts appear mixed. Initially, the authors relate slope orientation preferences based on latitude, higher obliquity excursions, and insolation-driven meltwater generation with both gullies and cirque-like alcoves (e.g., lines 673-681).

They also suggest that gullies can initiate through sediment flow assisted by either liquid water or CO2 ice sublimation. These are two different concepts, and the authors have mixed them. Please clarify this distinction and accordingly revise the paper.

Currently, it does not seem like the literature on gullies definitively agrees on one origin or another. Similarly, the trend that gullies shift from pole-facing to equator-facing around 40° in both hemispheres (e.g., Noblet et al., 2024) does not seem tied to a specific hypothesis. While overall equator-facing slopes are typically discussed in connection to liquid water, CO_2 cannot be completely ruled out either. We added the following paragraphs to Section 5.2.2 to address this comment:

"We suggest that the notches are gullies and would be able to act as necessary initiation points for ice accumulation that would later support glaciation and erosion to form cirque-like alcoves. However, the formation of cirque-like alcoves is not dependent on how the gullies are formed. Gully formation hypotheses currently include CO_2 ice sublimation, dry mass wasting, meltwater generation, and a combination of these factors. For example, meltwater generation is more commonly invoked for older, inactive gullies during periods of higher obliquity (e.g., Dickson et al., 2023; Noblet et al., 2024), while gullies that have been observed to be recently active invoke CO_2 frost, as well as dry mass wasting during frost-free seasons (e.g., Dundas et al. 2022).

While determining how gullies formed is outside the scope of this paper, we include a discussion of the current hypotheses. Dry mass wasting alone for gully formation has recently been challenged since the mean gradient of gullies is lower than the angle of repose of dry material on Mars (e.g., Noblet et al., 2024). Gullies that are either in 1) the northern hemisphere at latitudes lower than ~50° or 2) non-polar regions and are equator-facing are modeled to be inactive gullies (Roelofs et al., 2024). These inactive gullies are inconsistent with where CO_2 frost deposition is expected to occur on pole-facing slopes (e.g., Lange et al. 2023). For example, in the Southern hemisphere, CO_2 frost is only observed on pole facing slopes between 30-50°S and is not expected on equator-facing gullied slopes between 40°S and 50°S during current obliquity conditions (Noblet et al., 2024). Nevertheless, we note that CO_2 sublimation cannot be completely ruled out for equator-facing slopes since seasonal deposition of CO_2 frost at these latitudes could have been more prevalent in the past (Noblet et al., 2024). For present-day gully activity, rather than inactive gullies, sublimation of CO_2 is typically invoked (e.g., Dundas et al., 2022), though H_2O ice melt has been suggested to occur with dusty ice (e.g., Khuller et al., 2021).

Gullies are preferentially found on terrains that have subsurface water ice (Noblet et al., 2024). It is suggested that these inactive gullies are formed by melting of ground ice during past high obliquities (e.g., Noblet et al., 2024; Dickson et al., 2023). In addition, modeling found temperatures above freezing for meltwater and gully formation are possible during high obliquity excursions in the mid-latitudes (Costard et al., 2002; Williams et al., 2008; Williams et al., 2009; Dickson et al., 2023b). According to Dickson et al. (2023), at high obliquities of 35° in the past, meltwater is possible during the Amazonian because pressures exceed the triple point of water. Since increased surface meltwater has been linked to increased subglacial flow at the bed of polythermal glaciers (e.g., Bingham et al., 2006; Thomson and Copland, 2017), increased meltwater for glaciers would also likely lead to more wet-based glacial conditions and erosion (see Section 5.4 for arguments supporting wet-based glacier erosion). Future work is necessary to elucidate the potential relationship between gullying as initiation points for alcove formation and how that is tied to cyclicity in ice accumulation and melt."

My other concern, which would come alongside papers' revision, is that the authors have to present evidence that can substantiate the relationship between ice meltwater and gully formation on Mars. A lot of papers published during the last decade have provide vital inputs regarding the role of CO2 ice sublimation as the main driver for gully formation on Mars. So the authors would have to present evidence for the role of water if they wish to relate meltwater driven gullies as the initiation point for cirque-like alcoves.

The connection between cirque-like alcoves and gullies does not necessarily depend on the formation mechanism of each. Regardless of how the gullies formed, we use the southward bias, prevalence in the mid-latitudes, and geomorphic signatures for both features to propose that cirque-like alcove generation may be connected to where gullies previously existed. We agree that much of the recent literature points to CO_2 sublimation for active gully processes, with a few exceptions (e.g., Khuller et al., 2021). However, gullies that are either in 1) the northern hemisphere at latitudes lower than ~50° or 2) non-polar regions and are equator-facing are modeled to be inactive gullies (Roelofs et al., 2024). It is suggested that these inactive gullies are formed by melting of ground ice during past high obliquities (e.g., Noblet et al., 2024; Dickson et al., 2023). Since the southward-facing trend of the cirque-like alcoves in Deuteronilus Mensae correspond to the equator-facing aspect of these inactive gullies at these latitudes, it is possible that these cirque-like alcoves also formed during periods of high obliquity in association with the melting of water ice. We incorporated these points in the manuscript, which we included in the response to the above comment: "*Currently, the concepts…*"

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