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LETTER TO THE EDITOR

Late Quaternary micromammals and the precipitation history of the southern Cape, South Africa: response to comments by F. Thackeray, *Quaternary Research* 95, 154–156

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INTRODUCTION

We appreciate Thackeray's (2020) comments on our recent examination of late Quaternary micromammals from the southern Cape of South Africa (Faith et al., 2019). Focusing on the well-sampled sequence from Boomplaas Cave, we argued—controversially in Thackeray's (2020) opinion—that the micromammals indicated a transition from a relatively humid last glacial maximum (LGM) to a more arid Holocene. This is at odds with earlier interpretations of the region's climate history (e.g., Avery, 1982; Deacon et al., 1984; Deacon and Lancaster, 1988), though it is now supported by a growing body of evidence (e.g., Faith, 2013a, 2013b; Chase et al., 2017, 2018; Engelbrecht et al., 2019). We welcome this opportunity to clarify a few points raised by Thackeray (2020) and to further elaborate on our original interpretations.

MOISTURE AVAILABILITY, PRECIPITATION, AND TEMPERATURE

In Faith et al. (2019), our analysis and interpretation focused specifically on moisture availability (humidity/aridity). As defined in the paper, this variable is determined by precipitation relative to evapotranspiration. While it is common to conflate moisture availability with rainfall amount, as Thackeray (2020) has in his comment, this leads to confusion, as rainfall amount is only one factor determining moisture availability. As discussed by Chevalier and Chase (2016), moisture availability is largely determined by the combination of precipitation and temperature, through its influence on evapotranspiration. Thus, our interpretation of relatively humid conditions during the LGM at Boomplaas Cave should not be equated as implying relatively higher rainfall, as Thackeray (2020) has inferred.

To be clear, a relatively humid LGM could result from greater precipitation, cooler temperatures, or a combination of both. There is no question that cooler temperatures during the LGM would have contributed to greater moisture availability by reducing evapotranspiration (as suggested by Chase et al., 2017, 2018), but whether this was accompanied by higher or lower precipitation cannot be ascertained from our analysis. Indeed, we are skeptical that any analysis of faunal community composition can inform directly on rainfall amount sensu stricto, when it is moisture availability that determines habitat structure and the availability of the key resources (e.g., forage, standing water) on which faunas depend (Faith and Lyman, 2019). Faith et al. (2019) focused on moisture availability precisely because most organisms (both floral and faunal) are influenced by moisture availability rather than by rainfall amount—as a given amount of precipitation can have vastly different environmental consequences depending on how much of it is lost through evapotranspiration (e.g., Chevalier and Chase, 2016).

A SEMIARID CLIMATE

Thackeray (2020) observes that in our ordination of modern and fossil micromammal samples, the LGM assemblage from member GWA at Boomplaas Cave plots adjacent to several modern assemblages characterized by a semiarid climate. The emphasis Thackeray (2020) places on "semiarid"

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throughout his letter implies that some clarification is necessary, because the implication is that a semiarid LGM is inconsistent with our original interpretations. It is not. Following the United Nations National Environment Programme classification scheme (UNEP, 1997), a "semiarid" climate is characterized by mean annual precipitation (MAP) equal to 20%–50% of mean annual evapotranspiration (MAE), or aridity index (AI = MAP/MAE) values of 0.2 to 0.5. Boomplaas Cave today is at the lower limit of semiarid (AI = 0.24), yet the modern samples flagged by Thackeray (2020) are characterized by much greater moisture availability, with AI values of 0.43 to 0.48. Though not discussed by Thackeray (2020), the GWA assemblage also plots close to modern samples characterized by a "dry subhumid" climate (AI values of 0.5 to 0.65), further emphasizing its similarity to modern environments with greater moisture availability than the contemporary Boomplaas environment. Thus, the proximity of GWA to these semiarid and dry subhumid assemblages is fully consistent with our previous observation of a relatively humid LGM.

CUTTING THROUGH THE CONFUSION

Resolving the paleoclimatic history of the southern Cape has proven challenging in part due to a combination of seemingly contradictory lines of evidence (e.g., Avery, 1982, 2004) together with conflicting interpretations of the evidence (e.g., Deacon et al., 1984; Chase and Meadows, 2007; Faith, 2013a; Faith et al., 2019; Thackeray, 2020). These conflicts arise because many of the key archives provide only indirect —and at times uncertain—proxies for the climate variables in question. Indeed, many characterizations of the LGM as a time of harsh and arid conditions are based on ambiguous evidence (reviewed in Chase and Meadows, 2007), and this is particularly true of the records from Boomplaas Cave (see discussion in Faith, 2013a). For example, focusing on the micromammals, Avery (1982) once argued that low taxonomic diversity during the LGM was indicative of arid conditions, though she later showed that diversity was a poor predictor of precipitation (Avery, 1999). Thackeray's (1987) interpretation of an arid LGM was based on a micromammal-derived index that is only weakly correlated with precipitation (r^2 = 0.35), implying that it is strongly influenced by other (currently unknown) environmental parameters. Likewise, elevated frequencies of the bush Karoo rat (*Myotomys unisulcatus*) during the LGM have also been interpreted as indicative of aridity (Avery, 1982; Deacon et al., 1984; Thackeray, 1987)—most recently by Thackeray (2020)—yet this species occurs at similar if not higher abundances in environments that are considerably more humid than Boomplaas Cave is today (Supplementary Table 1 in Faith et al., 2019).

Because the reconstruction of paleoclimatic changes from the mammalian fossil record is fraught with potential pitfalls, confidence in the interpretations is enhanced when there is consistency between multiple independent lines of evidence (Faith and Lyman, 2019). Our interpretations provide just that. In Faith et al. (2019), we emphasized the broad similarities between our record of moisture availability and that provided by isotopic analysis of the Seweweeksport hyrax middens (Chase et al., 2017, 2018), located in a similar environment ∼70 km west of Boomplaas. Also important is that the nearby Cango Cave speleothem (∼3 km east of Boomplaas) shows a hiatus from the late glacial to the middle Holocene, signaling a lack of drip water availability (Vogel, 1983; Talma and Vogel, 1992). Deacon et al. (1984) struggled to reconcile this with their interpretations of an arid LGM transitioning to a humid Holocene, though the timing of the hiatus closely matches what we infer to be the most arid portion of the Boomplaas Cave sequence (Faith et al., 2019). In addition, a recent climate simulation suggests that the region would have received greater rainfall during the LGM relative to the present (Engelbrecht et al., 2019). In our view, the consistency within all of these records tips the scale in favor of the emerging understanding of the southern Cape's climate history—the transition from the LGM to the Holocene was characterized by increased aridity.

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