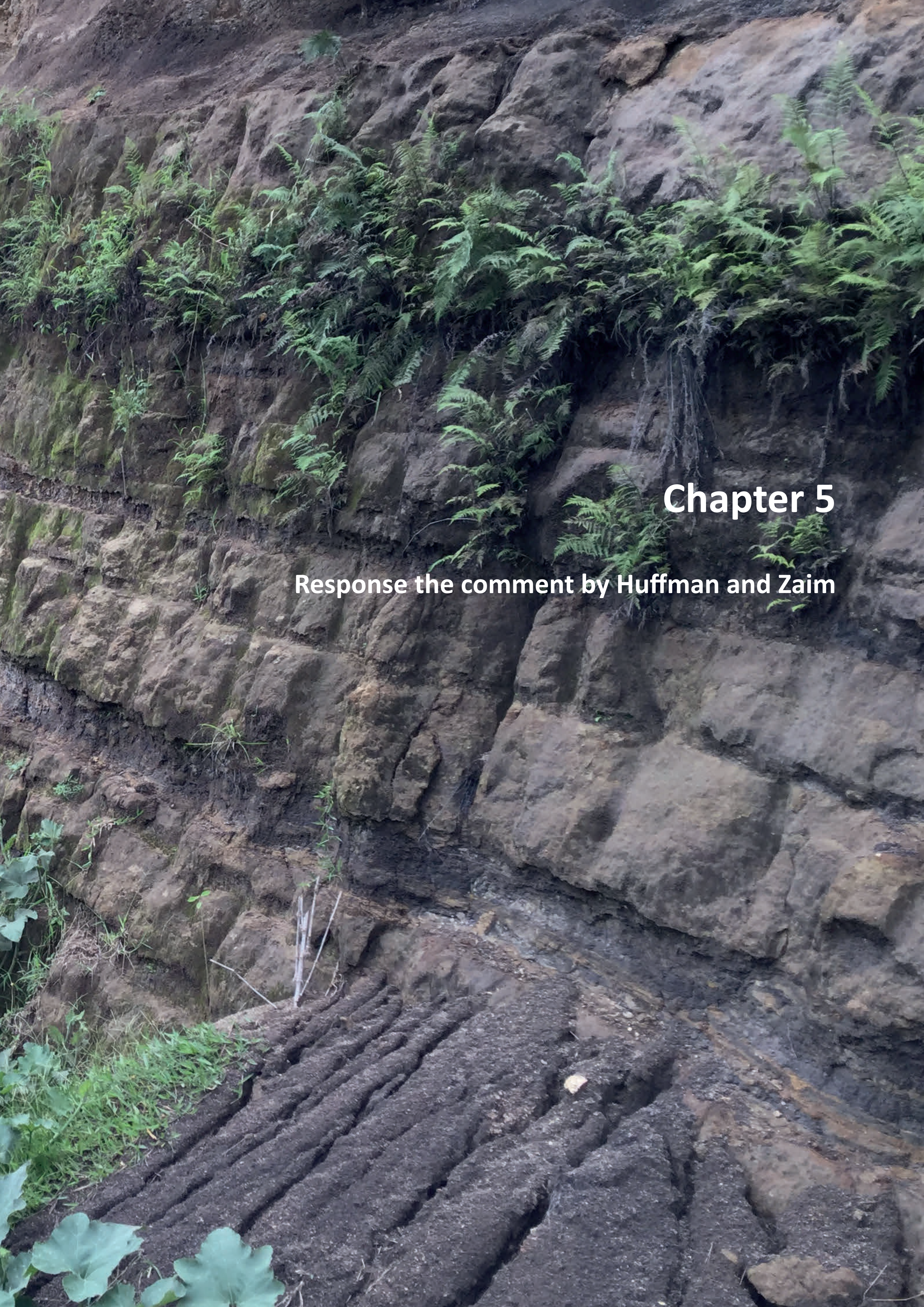
From the Solo to the Madura Strait: Quaternary geology, vertebrate palaeontology and hominin chronology of eastern Java and submerged Sundaland

Berghuis, H.W.K.

The deltaic sandstones of the Mojokerto area, quarry of Kepuh Klagen.

Chapter 5

Response the comment by Huffman and Zaim



CHAPTER 5

Response to the comment by Huffman and Zaim

H.W.K. Berghuis, Thijs van Kolfschoten, Shinatria Adhityatama, S.R. Troelstra, Sofwan Noerwidi, Rusyad Adi Suriyanto, Unggul Prasetyo Wibowo, Eduard Pop, Iwan Kurniawan, Sander L. Hilgen, A. Veldkamp, Josephine C.A. Joordens

Published in: *Quaternary Science Reviews* (2023)

Huffman and Zaim (2023) published a comment in Quaternary Science Reviews:

Geological age estimate for the Mojokerto child's skull Homo erectus; comment on Berghuis et al. "The eastern Kendeng Hills (Java, Indonesia) and the hominin-bearing beds of Mojokerto, a reinterpretation"

We gratefully accepted the offer by the journal to write a response. This became an interesting and valuable debate. For a full understanding and appreciation, the reader may have to refer to the published comment by Huffman and Zaim (2023).

Response to the comment by Huffman and Zaim

Huffman and Zaim criticize our analysis of the stratigraphic context and age of the *Homo erectus* child skull from Mojokerto. The disagreement stems from our different points of departure. Huffman and Zaim base their analysis and conclusions on sedimentological interpretations and stratigraphic models of the 1930's, wherein strata and their assumed ages are correlated over large distances across eastern Java (Duyfjes, 1936, 1938a).

In contrast, our recent studies in the Trinil (Berghuis et al., 2021) and Mojokerto areas (Berghuis et al., 2022) have revealed an area-specific intricate build-up of shallow marine and fluvial sequences, often separated by irregular incisive contacts, testifying of highly dynamic Pleistocene landscapes subject to volcanism, tectonism and sea-level fluctuations. For Trinil, our findings have in the meantime been confirmed by a detailed dating study (Hilgen et al., 2023). This underlines the need for a local instead of a regional sedimentological approach. We are aware that our observations and interpretations are often in sharp contrast with almost 100 years of geological and paleontological literature and it is understandable that this arouses confusion or disbelief. We are therefore pleased with the comments by Huffman and Zaim and with the opportunity given by QSR to respond.

Huffman and Zaim put forward several substantive matters that are interesting to discuss. For our response, we frequently refer to illustrations in our 2022 publication. For convenient reading, we added the composite stratigraphic column of the Mojokerto area (Fig. 9 of Berghuis et al., 2022) to this article as **Fig. 1A**. This may be held next to the stratigraphic column (Fig. 1C) of the comments by Huffman and Zaim.

The basis of their comment is that the authors insist that the hominin-bearing bed is part of a deltaic sequence. *The hominin-bearing lens occurs in deltaic strata ... (which) we informally refer to as the Klagen beds (Lines 41-43).* While understandable, this interpretation is incorrect and can easily be refuted. Indeed, the exposures are dominated by a conspicuous clinoform-bedded unit, consisting of fine tuffaceous sand with clayey interbeds, reflecting shallow-water deltaic progradation. We described this material in Section 4 of Berghuis et al. (2022) as Facies Association 4.

The material is nicely shown in the quarry photograph of Huffman and Zaim (Fig. 1D of their comment). The authors regard this photograph, which was first published in Huffman and Zaim (2003), as a textbook example of delta progradation, with foresets (indicated as B) overlain by topsets (indicated as A). The authors further state: *The A/B relationship and bed sets … are pertinent to determining the geological age of the discovery area succession (Lines 64 – 65).* However, as the two insets of their picture show, there is no sedimentological or lithological difference between B and A, except for a difference in clinoform dip. This is a very common feature within the deltaic series of this area. The strata form sets, representing superimposed deltaic progradation sequences. See for good examples Fig. 4 (photo 11) and Fig. 5 (photo 11) of Berghuis et al. (2022). The contact between these bed sets are internal unconformities, which may have different backgrounds, such as a shifted position of the distributary channel, a short pause in the supply of fresh volcanic ash, or a sea-level change. Individual deltaic sets may have a somewhat different clinoform dip (value and direction). Indeed, one of the interesting features of the deltaic strata of Mojokerto is the relatively steep dip of the lowest clinoform set. This probably relates to deltaic progradation under sheltered conditions, which may have been an interdistributary lagoon or a coastal lake (see section 6.5 of Berghuis et al., 2022). In any case, the B-A contact, by Huffman and Zaim indicated as an important (*pertinent*) boundary between foresets and topsets is in fact 'only' a boundary between two clinoform sets. Bed set A has a lower dip, which gives an appearance of a foreset-topset relation. Note that the quarry photograph (Fig. 1D of the comments) only offers a single perspective and that Huffman and Zaim do not specify the view direction or any measured clinoform dip. Note also that we indicated a similar (possibly the same) build-up of two superimposed clinoform sets in our composite stratigraphic section (**Fig. 1A of this article**).

Thus, having misidentified foresets for topsets, Huffman and Zaim proceed by stating that the fluvial conglomerates overlying the deltaic series (in their Fig. 1C indicated as MS or monument sandstone) are part of this 'topset association'. In their text: … *the marine topsets that concordantly underlie the MS (Line 83)*. However, the conglomerate bed has a sharp lower boundary, truncating the underlying deltaic strata, certainly not concordantly, which would also be highly unusual for a fluvial channel lag. The authors probably intend to say that they regard the conglomerate bed to be part of their 'topset association'. Indeed, the deltaic beds and the overlying horizontal fluvial bed have the appearance of a foreset-topset relation. The fact that the contact between these elements is erosive (instead of more gradual or sigmaoid) is not in conflict with such an interpretation, but would merely indicate a stagnant or falling baselevel during delta progradation.

However, a great difference in texture and sediment composition shows that the deltaic beds (all of which are foresets) and the overlying conglomerates cannot represent one and the same system of deltaic progradation. The deltaic strata are made up of fine-grained volcanic ash with scarce fine, angular pumice gravel. The overlying fluvial bed is a polymict conglomerate with medium to coarse, well-rounded andesite clasts. Whereas the deltaic series represents a coastal landscape-setting under an extremely high supply of suspended fine-grained volcanic matter by ash-choked rivers, the conglomerate reflects a large and stable river landscape, with long-distance bedload transport of erosion material from the volcanic hinterland. The lower boundary of the conglomerate must therefore be a younger fluvial truncation of the delta body, representing a hiatus in the depositional record, which makes this contact the real *pertinent* stratigraphic boundary of the Mojokerto section.

Huffman and Zaim proceed to add all overlying fluvial strata to the delta sequence: *The Klagen beds are best interpreted as the product of a prograding, river-dominated, sand rich marine delta lobe (Line 92).* This is a peculiar interpretation, which implies that this deltaic sequence is made up of ~15 m of foresets overlain by ~ 40 m of topsets (thicknesses based on the stratigraphic column of Huffman and Zaim, Fig. 1C). It is hard to imagine a landscape background for such a sequence. The deposition and preservation of this thick, uninterrupted topset series would have required a situation of considerable sea-level rise, whereas at the same time deltaic progradation continued and the delta plain did not drown. Note also that according to the landscape sketches of for example Huffman et al. (2007) the coastline was always in the immediate vicinity. This is a very unlikely representation of the coastal landscape. Remarkably, the authors suggested in Huffman and Zaim (2003) that this thick 'topset series' may relate to a glacio-eustatic drop in sea level, a statement that was repeated in Morley et al. (2020), to which Huffman and Zaim contributed as co-author. This is a puzzling statement. A lowstand would cause emergence and incision of the coastal delta and not the accumulation of a 40 m thick 'topset' series.

In Berghuis et al. (2022) we presented a new landscape model, in which the fluvial series is unrelated to the underlying deltaic series. We showed that the fluvial series has a cyclic build-up of three stacked fluvial sequences **(Fig. 1A of this article)**, each with an erosive base marked by a conglomerate bed, which we regard as fluvial aggradation - degradation cycles on a subsiding floodplain. They relate to a large river system, which may be the early Brantas. We tentatively linked the fluvial sequences to Middle Pleistocene sea-level fluctuations (**Fig. 1B of this article**. See for a detailed explanation Section 6.7 of Berghuis et al., 2022). The vertebrate fossils are concentrated in the conglomerate beds marking the base of the fluvial sequences. The third fluvial cycle grades into marine clays, which shows that eventually the floodplain drowned, a transgression which we tentatively linked to MIS11.

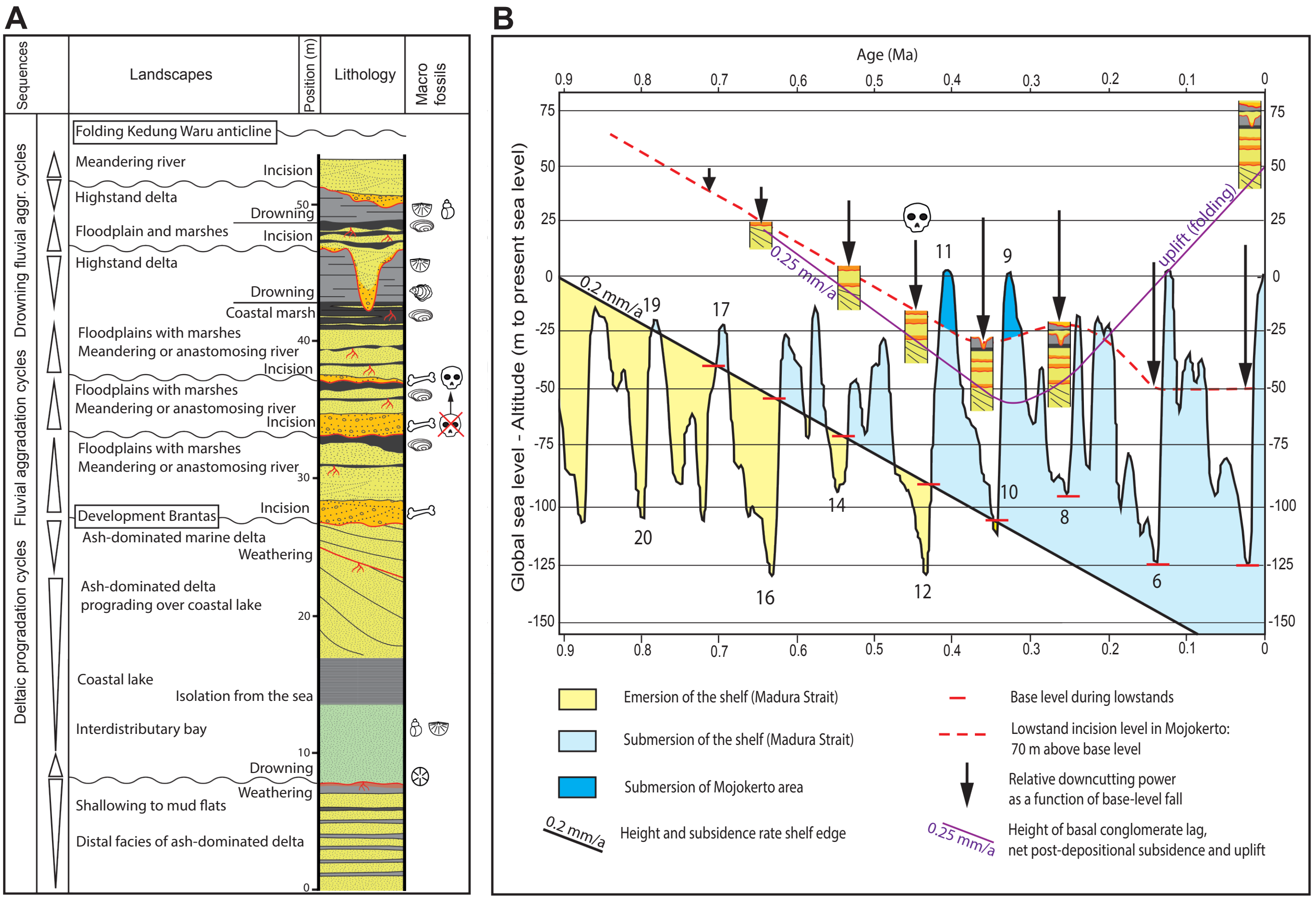


Fig. 1. A: Composite stratigraphic column of the Kedung Waru anticline north of Mojokerto, based on quarry sections east of Kepuhklagen Road. From: Berghuis et al. (2022). Please refer to this paper for detailed facies descriptions. Note the revised stratigraphic level of the Perning Homo erectus skull. **B:** Reconstruction of successive fluvial cycles in relation to sea-level fluctuations and subsidence. From: Berghuis et al. (2022). Please refer to this paper for more information. Based on the comment by Huffman and Zaim we changed the correlation of the 1936 find level of the Perning skull to the conglomerate lag that forms the base of the third fluvial sequence, suggesting an MIS12 age for the hominin-bearing layer. Sea-level curve based on Bintanja and van de Wal (2008).

With respect to the position of the hominin-bearing bed within these fluvial sequences, Huffman and Zaim bring in an important observation. The authors state: … *mudstone with paleosol development overlies the PB* (Perning Bone bed) *and the burrowed sandstone marking the subsequent marine flooding (Line 77).* The authors base this observation on their excellent study to relocate the 1936 find site of the *Homo erectus* skull, which included site clearance and test excavations and yielded a detailed stratigraphy of the skull discovery site (Huffman et al., 2006). The find site lies just outside the large new quarries and is today fully overgrown. In the field, we correlated the 1936 find site with the conglomerate bed that marks the base of the second fluvial sequence. However, the observation of Huffman and Zaim indicates that our correlation is incorrect and that the hominin skull actually derives from the overlying conglomerate bed, which marks the incisive base of the third fluvial sequence **(Fig. 1A of this response to comment)**. Referring to our correlations with the sea-level curve **(Fig. 1B)**, this ties the hominin-bearing conglomerate to MIS12 (instead of MIS14, as was suggested in Berghuis et al., 2022), giving a revised age estimate of ~450 ka.

We hope that we have been able to clarify our interpretations, and we are grateful to Huffman and Zaim for pointing out their detailed observations of the sediments at the *Homo erectus* find site, thus allowing us to further refine our correlation with the sea-level curve.