Climate of the Past Discussions

Clim. Past Discuss., author comment AC2
https://doi.org/10.5194/cp-2021-161-AC2, 2022

Comment on cp-2021-161

Fabrizio Marra et al.

Author comment on "Terrestrial records of glacial terminations V and IV and insights on deglacial mechanisms" by Fabrizio Marra et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2021-161-AC2, 2022

Point by point answers to Reviewer #1's comments

- Evidence for glaciers in the Apennines. The reviewer states that the weakness of the paper is that for having glaciations it needs glaciers and these are not reported. We will report the evidence of glaciations according to Giraudi (2011) in Figure 1 and add reference to this work.

- Geological background. All the long paragraph in which the reviewer describes in detail the features of the Present-day Liri catchment basins are irrelevant with respect to the topics of our work which is focused on the fluvial-lacustrine deposits emplaced 450 and 350 ka within a completely different morpho-structural basin. As a matter of facts, two several meter-thick coarse gravel horizons were emplaced within the Liri basin 450 ka and 350 ka, as evidenced by the 40Ar/39Ar age constraints provided in the paper.

Regarding the hypothesized tectonic structures, most of those reported in Figure 1 are based on a wide literature (e.g., Cardello et al., 2020; Centamore t al., 2010; Sani et al., 2004). For what concerns faults A and B, the fact that they are not reported in the recent geological map doesn't necessary imply that they do not exist. The 1:50.000 geologic map is based on the survey of surface evidence; in contrast, the inferred faults are hypothesized based on the interpretation of original subsurface chronostratigraphic data provided in our work.

The surface effects of these faults, even if they were active until 250 ka, only (that's during the climax of the extensional phase that affected this portion of the Apennines and was followed by a steady tectonic uplift since 250 ka), can be detected in the morpho-structural features of the Liri basin highlighted in Figure 1a.

- Regarding the concerns about sedimentologic characterization, it is clearly stated in the paper:

Also due to the fact that several geologic sections that are included in this study are no longer exposed and stratigraphic data have been obtained from the literature, here we adopt a relatively simple but effective sedimentological approach based on the identification of three main granulometric classes, aimed at providing information on the energy of transport and the related sedimentary environments within the Sacco-Liri catchment basin:

- *coarse gravel (max diameter of pebbles >2 cm), tractive fluvial environment of high transport energy;*
- *coarse sand with sparse fine gravel (max diameter of pebbles ≤2 cm), fluvial environment of mid transport energy;*

iii. silt, clay and carbonate-rich mud; lacustrine and, subordinately, alluvial environment of low transport energy.

However, for assurance of the reviewer, author Italo Biddittu originally investigated all the geologic sections reported in previous literature, providing a detail documentation of their stratigraphy, which is far enough to accomplish the goals of the present study, and can report on the correctness of the descriptions provided in the paper.

Moreover, myself, Fabio Florindo and Giovanni Muttoni have re-analyzed cm by cm the sedimentologic features of the cores of the two boreholes previously described in Muttoni et al. (2009) and presently hosted at the Milano University.

Finally, all the sedimentologic details that the reviewer mentions have no direct implication on the topics of our study.

- Geochronology. The reviewer is evidently not a geochronologist and has not carefully read the explanation of the principles on which the detrital sanidine method is based. Indeed, the accuracy, as well as the limitations of the $^{40}Ar/^{39}Ar$ ages are clearly and thoroughly discussed in a dedicated section (*3.3 Detrital sanidine dating approach*). Moreover, all the dated samples are discussed one by one in a dedicated supplementary text (*Supplementary Material #1B - Age data and interpretations*).

We briefly report here some considerations:

The youngest crystal (or the youngest crystal population in case two or more crystals yield consistent ages at two sigma) in the sedimentary samples provides a maximum age (*terminus post quem*) to the time of deposition of the sediment (i.e., the age of the sediment must be younger or equal to that of the youngest crystal(s)). However, as discussed in Marra et al. (2019), the occurrence of continuous eruptive activity throughout the Middle-Upper Pleistocene in the volcanic districts of central Italy allows to assume the lack of younger ages corresponding to known, large eruptions as a relative upper age-constraint. Indeed, incorporation of crystals from the youngest, stratigraphically higher eruption has higher probability with respect to those of older eruptions, and their absence should be considered statistically improbable when a large number of crystals (e.g., ~30) is dated. Therefore, it is reasonable to assume that the time of emplacement must be close to the youngest population age.

Also regarding the sedimentation rates, the reviewer seems to have not read the supplementary material in which this issue is discussed in detail. We report here the full discussion of the ages of the two samples collected in the Ceprano boreholes and their implication on the sedimentation rate:

Samples CE-1, CE-2 (this work)

Sample CE-1 was collected in borecore Ceprano 1 at 39.3 m depth within a coarse gravel layer with abundant sand matrix. The youngest crystal out of a population of 30 extracted from this sediment yielded a 40Ar/39Ar age of 452.4±1.8 ka (2☐ uncertainty). Sample CE-2 was collected at 15.1 m depth in borehole Ceprano 2, at the base of a coarse sand layer and yielded a youngest crystal date of 389.6±2.7 ka (2☐ uncertainty).

These two maximum ages can be regarded as statistically significant even if based on one single crystal. The Ceprano boreholes were drilled in Campogrande which is located on the left hydrographic side of the Sacco catchment basin, a sector draining the most active and densely vent-populated volcanic area of the Volsci Volcanic Field. A climactic eruptive phase occurred at the VVF in the interval 420 - 350 ka9, so the lack of crystals younger than 453 ka is strongly suggesting that the emplacement of the sand deposit occurred before the start of this volcanic phase. Consistent with this hypothesis, there is one crystal of 428±10 ka along one youngest crystal of 390±3.6 ka in the sample stratigraphically above. Moreover, these two ages along with that of 350.8±8 ka on the primary layer occurring at the top of the sedimentary succession recovered in the Ceprano boreholes10 provide a constant sedimentation rate of 38 cm/ky (see Figure 4 in the main text), which accounts for the exactness of these ages.

Therefore, it is reasonable to assume that also the maximum ages derived from reworked sanidine crystals can be regarded as providing precise time constraints to sediment deposition, as the one on the primary volcanic layer.

Indeed, and age close to 453 ka for the gravel deposition during MIS 11 is in perfect agreement with the constraints provided from the Paleo-Tiber aggradational successions, which bracket it between 451±2 and 445±3 ka11 (Figure 8 in the main text).

- Forcing mechanism on gravel deposition. The reviewer states that the hypothesis considered for gravel deposition, i.e.: deglaciation process, is the most unlikely. However, 25 years of dedicated literature contradict this statement:

Alvarez, W., Ammerman, A.J., Renne, P.R., Karner, D.B., Terrenato, N., Montanari, A., 1996. Quaternary fluvial-volcanic stratigraphy and geochronology of the Capitoline hill in Rome. Geology 24, 751-754.

Karner, D.B., Marra, F., 1998. Correlation of fluviodeltaic aggradational sections with glacial climate history: A revision of the Pleistocene stratigraphy of Rome. Geological Society of America Bulletin 110, 748–758.

Karner, D.B., Renne, P.R., 1998. 40Ar/39Ar geochronology of Roman volcanic province tephra in the Tiber River valley: Age calibration of middle Pleistocene sea-level changes. Geological Society of America Bulletin 110, 740-747.

Marra, F., Florindo, F., Karner, D.B.,1998. Paleomagnetism and geochronology of early Middle Pleistocene depositional sequences near Rome: comparison with the deep sea □18O climate record. Earth and Planetary Science Letters, 159, 147-164.

Florindo, F., Karner, D.B., Marra, F., Renne, P.R., Roberts A.P., Weaver, R., 2007. Radioisotopic age constraints for Glacial Terminations IX and VII from aggradational sections of the Tiber River delta in Rome, Italy. Earth and Planetary Science Letters 256, 61-80. doi: 10.1016/j.epsl.2007.01.014.

Marra, F., Florindo, F., Boschi, E., 2008. History of glacial terminations from the Tiber River, Rome: Insights into glacial forcing mechanisms. Paleoceanography 23, 1-17. doi:10.1029/2007PA001543

Marra, F., Bozzano, F., Cinti, F.R., 2013. Chronostratigraphic and lithologic features of the Tiber River sediments (Rome, Italy): implications on the Post-glacial sea-level rise and Holocene climate. Global and Planetary Change. https://doi.org/10.1016/j.gloplacha.2013.05.002

Grant, K.M., Rohling, E.J., Ramsey, C.B., Cheng, H., Edwards, R.L., Florindo, F., Heslop, D., Marra, F., Roberts, A.P., Tamisiea, M.E., Williams, F., 2014. Sea-level variability over five glacial cycles. Nature Communications 5, 5076. doi:10.1038/ncomms6076

Marra, F., Rohling, E.J., Florindo, F., Jicha, B., Nomade, S., Pereira, A., Renne, P.R., 2016a. Independent 40Ar/39Ar and 14C age constraints on the last five glacial terminations from the aggradational successions of the Tiber River, Rome (Italy). Earth Planet Sci. Lett. 449, 105-117. doi:10.1016/j.epsl.2016.05.037

Marra, F., Florindo, F., Anzidei, M., & Sepe, V., 2016b. Paleo-surfaces of glacio-eustatically forced aggradational successions in the coastal area of Rome: assessing interplay between tectonics and sea-level during the last ten interglacials. Quaternary Science Reviews 148, 85-100. http://dx.doi.org/10.1016/j.quascirev.2016.07.003

Marra, F., Jicha, B., Florindo, F., 2017. 40Ar/39Ar dating of Glacial Termination VI: constraints to the duration of Marine Isotopic Stage 13. Scientific Reports 7, 8908. doi:10.1038/s41598-017-08614-6

Luberti, G.M., Marra, F., Florindo, F., 2017. A review of the stratigraphy of Rome (Italy) according to geochronologically and paleomagnetically constrained aggradational successions, glacio-eustatic forcing and volcano-tectonic processes. Quaternary International, 438, 40-67. http://dx.doi.org/10.1016/j.quaint.2017.01.044

Marra, F. Costantini, L., Di Buduo, G.M. Florindo, F., Jicha, B.R., Monaco, L., Palladino, D.M., Sottili, G., 2019. Combined glacio-eustatic forcing and volcano-tectonic uplift: geomorphological and geochronological constraints on the Tiber River terraces in the eastern Vulsini Volcanic District (central Italy). Global and Planetary Change 182,103009. doi:10.1016/j.gloplacha.2019.103009.

Pereira, A., Monaco, L., Marra, F., Nomade, S., Gaeta, M., Leicher, N., Palladino, D.M., Sottili, G., Guillou, H., Scao, V., Giaccio, B., 2020. Tephrochronology of the central Mediterranean MIS 11c interglacial (~425-395 ka): new constraints from Vico volcano and Tiber delta, Central Italy. Quaternary Science Reviews 243: 106470.

Giaccio, B., Marino, G., Marra, F., Monaco, L., Pereira, A., Zanchetta, G., Gaeta, M., Leicher, N., Nomade, S., Palladino, D.M., Sottili, G., Guillou, H., Scao, V., 2021. Tephrochronological constraints on the timing and nature of sea-level change prior to and during glacial termination V. Quaternary Science Reviews, https://doi.org/10.1016/j.quascirev.2021.106976

Marra, F., Pereira, A., Boschian, G., Nomade, S., 2021a. MIS 13 and MIS 11 aggradational successions of the Paleo-Tiber delta: geochronological constraints to sea-level fluctuations and to the Acheulean sites of Castel di Guido and Malagrotta (Rome, Italy), Quaternary International, in press. https://doi.org/10.1016/j.quaint.2021.12.016

- Figures. We will take into account the suggestions to improve clarity of the figures.