Regarding comments from Reviewer #2: Blas Valero

The figures are informative and well-designed, but I would suggest a few edits to some of the figures:

The size and colors of some lettering in Figures 2 and 3 could be changed to make them easier to read.

Answer: **Thanks. We have made some changes in both figures in order to make them more readable (see our answers to the comments from reviewer #1).**

Figure 1. It could include also a figure with main climate features of the region.

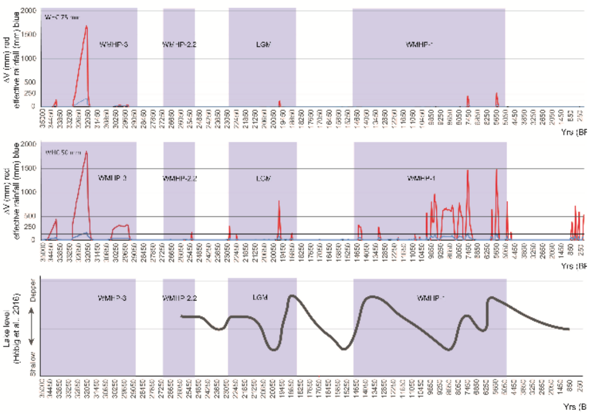
Answer: **We have added the main climates features in this figure.**

Figure 3. It could also include the topography, so the drainage and the delineation of the subbasins would be easier to visualize

Answer: **Figure 3 already includes a hillshade and some topographic points. We have added more topographic landmarks, including river names to make it more informative.**

Figure 4. It could include all paleoclimate periods, plus de main humid periods identified in El Padul record (Camuera et al. 2022). As an inset it could also include the correlation between recent SST in Alborán and weather stations close to FdP.

This is the new Fig. 4:



Answer: **As the referee indicates, there is a lack of climatic information in the MS. We agree with that and have included other climatic periods in this figure in addition to the LGM. Regarding the correlation between recent SST in Alborán and weather stations close to the FdP: We made a correlation between the SST (using Cabo de Gata buoy) and land temperature (Antequera weather station) during an instrumental period of more than 20 years (2000-2023) and we obtained a correlation coefficient of 0.76. We added it in the new version of the MS.**

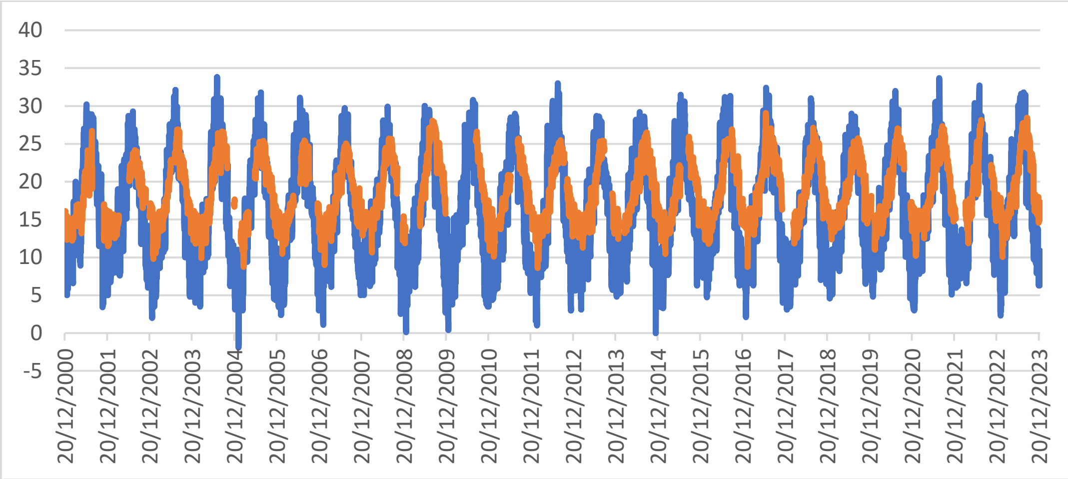


Fig. A (for revision). Temperature in the weather station of Antequera (blue line) and in the Cabo de Gata buoy from 2000 to 2023.

Figure 6. Any lake level inferences for central core based on gypsum crystals morphologies?

Answer: **Thanks. The lithology of core 2012-PL1 from the central FdP is not as well defined as in core 2013-04, from the lake shore. As stated in section 4.2, the upper 20 cm of core 2012-PL1 are dominated by laminated grey clays intercalated with mm-thick layers of gypsum sand. Between 20 and 120 cm depth, the core is composed of pale carbonate mud with embedded prismatic gypsum macrocrystals of cm-scale. Since we suspect that part of the lake sediments in the central/northern are of FdP has been eroded away and transported to the southward areas (see discussion), lake level reconstruction from gypsum morphologies in this core is not possible.**

Figure 7. To better understand the similarities with previous work it should also include the lake level reconstruction by Höbig et al (2016) and the paleoprecipitation and main humid periods by Camuera et al (2022).

Answer: **We included in figure 4 the lake level reconstruction by Höbig et al., 2016 to compare with the main humid periods described by Camuera et al., 2022.**

Figure 10. Include the location of the 15 m (NE) and 10 m (S) deposits.

Answer: **Thanks, we have included both locations in the new MS.**

A final figure showing the depositional evolution of the lake, the paleoprecipitation, lake level reconstructions (both model and sediment cores), regional paleoclimate and regional and local tectonics would be a good summary of the manuscript.

Answer: **Both reviewers suggested the addition of a final summarizing figure taking together tectonics, sedimentation, climatologic and hydrologic features. In order to accomplish such suggestions, the new version of the MS, we made a simplified figure showing the FdP playa-lake evolution at different stages from 35,000 years until present.**

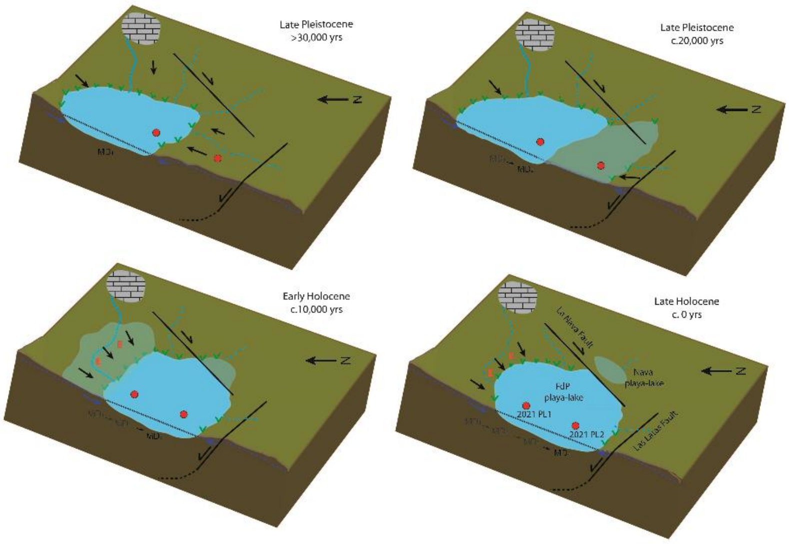


Fig. 13. Summarizing sketch of FdP playa-lake evolution according to our tectonic, hydrogeological and sedimentological results.

I have several suggestions regarding the integration of previous data and the interpretation of some results (see below).

Paleoclimate. Paleoprecipitation reconstruction for Padul pollen record has to be considered with caution, as the authors stated in the original paper. Camuera et al (2022) paleoprecipitation reconstruction showed several humid periods during the last 200 ka, some of them during the life span of FdP: WMHP-3 (39–29 kyr BP), WMHP-2 (27–18.5 kyr BP; WMHP-2.2 at 27–25 kyr BP and WMHP-2.1 at 23–18.5 kyr) and WMHP-1 (15.5–5 kyr BP). These periods should be discussed in the manuscript and marked in Figure 4. AS I mentioned before, in this Figure it would be helpful to indicate also all the paleoclimate periods, not only the LGM.

Answer: **Thanks. We have included some climatic periods in Fig. 4, according to the reviewer´s comment. In the discussion section, we have better explained the importance of climatic variability on the hydroperiod of the FdP playa-lake. We included this: "During some extremely wet periods described by Camuera et al. (2022) such as WMHP-3 (39–29 kyr BP), WMHP-2 (27–18.5 kyr BP; WMHP-2.2 at 27–25 kyr BP and WMHP-2.1 at 23–18.5 kyr) and WMHP-1 (15.5–5 kyr BP), the FdP playa-lake probably enlarged its hydroperiod to more than 80%. Indeed, it could have behaved as a permanent lake during short periods, as it currently occurs with other lakes in this area (e.g. Amarga Lake; Jiménez-Bonilla et al., 2023)."**

Line 454 "As can be deduced from Fig. 8, FdP playa-lake has been dry almost every summer, during the period with instrumental records (1983 – 2022) except for two humid periods (1996-1997 and 2010-2011) in which the playa-lake remained flooded for two consecutive years. From the analyses of the data record obtained in the deepest part of the playa-lake's floor, during the daily record of the lake's hydroperiod, 9710 out of 14610 days, water level was higher than 409,54 m A.S.L. which is the altitude in which level drops to zero m (consequently, the playa-lake dry-out completely). So the average flooded period (hydroperiod) for this playa-lake, to date, is 66,5% (see Fig. 8 for details)."

The SST reconstructed from the Alborán Sea site is considered comparable to FdP air temperature (Line 320). To increase the strength of the argument, the authors could explore the correlation between SST and land temperature (weather stations) during the instrumental record.

Answer: **As suggested by the reviewer, we have made a correlation between the SST (using Cabo de Gata buoy) and land temperature (Antequera weather station) during an instrumental period of**

20 years (2000-2020) and we obtained a correlation coefficient of 0.76. We added it in the new version of the MS.

Hydrogeology. The hydrological modeling requires "constant watershed surface area for past 35 kyrs" (Line 188). However, the authors invoke a clear role of neotectonics, changing the basin configuration, as the depocenter shifted and , some areas - as La Nava subbasin - were also part of the watershed. These changes add some uncertainty to the model that could require further discussion.

Answer: **In the MS we explain that the FdP watershed mostly remained constant during its evolution (See: "Some plausible increases/decrease on the FdP watershed (<10 km^2, 6% of the current watershed) would not imply significant increases on the W/AFS relationship (Fig. 12)." Neotectonics partially affected the FdP watershed configuration but did not change its area, which mostly remained constant during the 35 Kyrs. Active faults mostly affected the FdP playa-lake (its flooded area). As reviewer #1 suggested, we have clarified the meaning of FdP watershed and FdP playa-lake and we tried solving this confusion in the current MS version. Moreover, in order to make it clearer, now we say: "Although the watershed geometry could have changed, the FdP watershed area probably maintained."**

For the non - hydrogeology audience some concepts as "water holding capacity" could be explained a little bit more in detail beyond including a reference (Rodriguez Hernández et al., 2007).

Answer: **We have clarified this concept. We state now that: "The WHC is the amount of water a soil can hold without generating runoff and it depends on the soil texture".**

Although there are many references to previous work, there is no detailed hydrogeological synthesis from FdP. Both surface and subsurface watersheds are considered comparable (Kohfahl et al., 2008) but there is no description of the nature and extension of the aquifers and subsurface flows. The authors suggest possible flows from the carbonate aquifer of Mollina mountain range) Santillán stream; Fig. 3) and, most probably, groundwater inputs also from the Sierra de Humilladero mountain (line 143), but some information could be included about the volume and hydrologic properties of such aquifers and hydrogeological data ruling out long distance groundwater inflows.

Answer: **For our calculations, the runoff coming the karstic aquifers is included within the BD. We have included: "*BD* includes the groundwater coming from the karstic aquifers and the surface runoff coming from all the FdP playa-lake." to make it clearer.**

"…although no springs have been observed in this carbonate aquifer. Both aquifers are intensively exploited at present (e.g., Rodríguez-Rodríguez et al., 2015), but in natural regime there are estimations of the recharge in both aquifers being 25-30% of the average precipitation in the region (c. 440 mm/year) (Martos-Rosillo et al., 2015)"

Martos-Rosillo, S., González-Ramón, A., Jiménez-Gavilán, P., Andreo, B., Durán, J. J., & Mancera, E. (2015). Review on groundwater recharge in carbonate aquifers from SW Mediterranean (Betic Cordillera, S Spain). *Environmental Earth Sciences*, *74*, 7571-7581.

For the lake level calculations, the authors considered that water inputs only come from the watershed (Line 188), which is assumed to have remained constant over the past 35 kyrs. What about changes in the groundwater fluxes to the basin from the surrounding aquifers during the last 35 kyrs?.

Answer: **As we mentioned in the previous comment, for our calculations, groundwater runoff is included in Basin discharge (BD). See how we simplified the water balance from equation 1 to equation 2 in the Methodology section. Moreover, as the climatic conditions do not change**

significantly during the last 35 kyrs, the FdP playa-lake probably behaved as a discharge system since its inception and groundwater fluxes to the basin probably remained constant. We have included: "With these climatic conditions, the FdP playa-lake probably behaved as a discharge system since its inception." to make it clearer.

One of the main aims of the manuscript is to analyze the role of climate variability and tectonics activity in lake level changes, but the argument could be stronger if the data sets were compared in the text and the figures. The results of the hydrological modeling (Fig 7) could be plotted with the FdP lake level reconstructions (Höbig et al., 2016) and with Padul paleoprecipitation (Camuera et al., 2022). How the ca 32, 30, 20, 9.8-7.5, 6-5 and 0.8 - 0.25 ka BP higher lake level periods inferred by the hydrological model correspond to those derived by the lake sequence and the regional humid periods interpreted in Padul?. With caution due to the uncertainties of the age model, Höbig et al. (2016) suggested several phases of flooding at LFP, when lake level was low and the runoff increased (ca. 4.5 ka cal BP, 9 ka cal BP, 14.8 ka cal BP, and 18 ka cal BP) and periods of relatively higher lake level during the LGM, HE1, YD, around 8.2 and 4.2 ka. Camuera et al. (2022) identified several regional humid periods: WMHP-3 (39–29 kyr BP), WMHP-2 (27–18.5 kyr BP; WMHP-2.2 at 27–25 kyr BP and WMHP-2.1 at 23–18.5 kyr) and WMHP-1 (15.5–5 kyr BP). Interestingly, the paleohydrological model for FdP shows higher lake levels at around 30 ka, LGM early to mid Holocene and the last centuries. The FdP reconstruction based on sediment sequence (Höbig et al., 2016) showed also higher lake levels during the LGM and some periods of the Late glacial, but an opposite trend during the Holocene with relatively lower lake levels during the early and mid Holocene. Annual recharge of the aquifers during winter rainfall could be a stronger proxy for lake level variability and seasonality of precipitation could play a large role in paleohydrology of FdP. All these coherences and discrepancies should be addressed in the discussion.

Answer: **This is a really interesting point and we have included this comparison in figures. Moreover, we made another figure summarizing the FdP evolution at different stages (Fig. 13 in the new version of the MS). We have also included in the discussion the importance of the climatic variability on the FdP hydroperiod: "During some extremely wet periods described by Camuera et al. (2022) such as WMHP-3 (39–29 kyr BP), WMHP-2 (27–18.5 kyr BP; WMHP-2.2 at 27–25 kyr BP and WMHP-2.1 at 23–18.5 kyr) and WMHP-1 (15.5–5 kyr BP), the FdP playa-lake probably enlarged its hydroperiod to more than 80%. Indeed, it could have behaved as a permanent lake during short periods, as it currently occurs with other lakes in this area (e.g. Amarga Lake; Jiménez-Bonilla et al., 2023)." Comparing with the lake level reconstruction of Höbig et al., 2016 we included in the discussion: "Comparing our lake level reconstruction with that one of Höbig et al. (2016), based on sediment sequence, we observe that the lake level is higher during the LGM and some periods of the Late glacial, but an opposite trend during the Holocene with relatively lower for the Höbig et al. (2016) reconstruction (Fig. 7). It could be due to a recharge to the karstic aquifers during the winter."**

I find a very suggestive outcome of the model that lake level stabilized during wet periods at 5 m higher than current level. The model considered extremely rainy periods of 50 yrs (P =700 mm, ETP = 850 mm and runoff = 75 mm; Fig. 7B) and the water level stabilizes when water inputs are equal to water outputs. Could higher groundwater inputs during humid periods have increased the water balance and allowed higher lake levels?.

Answer: **This is an interesting issue. Our model does not contemplate the case of extremely wet periods (Fig. 9), when the water level could be much higher than nowadays. However, during the last decades, which include wet periods with P > 1000 mm/yr, the piezometric level remained stable (Rodríguez-Rodríguez et al., 2016). In the case of greater increase of groundwater level, the AFS would increase because of a water supply from the aquifer, the W/AFS relationship would reduce and then, the equilibrium would be reached before 17 years, but at the same lake level: 5 m. We have included this question in the new version of the MS: "This lake level could be reached before 14 years in case of groundwater level increases." And in the discussion: "During these extremely wet periods, our model does not contemplate a possible water supply from the aquifer, which would reduce the time to reach the maximum water level."**

Other factors that could change the outcome of the model are related to the changes in watershed (W) versus lake basin (AFS) surface areas. Although it is clear the importance of the flat bathymetry of the FdP playa-lake as the W/AFS relationship decreases when the FdP water level increases. But as I understand it that is based on the assumption that watershed surface area is in equilibrium with average flooded surface and that seems counter intuitive with large tectonic changes in the basin. A premise of the model is that W/AFS is constant, and at the same time, areas as La Nava Playa lake were formerly part of the FdP playa lake and had been subsequently separated by the uplift of La Nava fault footwall. Are there any data or hypothesis about when did La Nava subbasin surface drainage was individualized?; Are FdP and La Nava still connected via groundwater flows? .

Answer: **In the MS we suggest that the FdP watershed's size didn't change much during its evolution (See: "Some plausible increases/decrease on the FdP watershed (<10 km^2, 6% of the current watershed) would not imply significant increases on the W/AFS relationship (Fig. 12)." In the previous MS). Neotectonics partially affected the FdP watershed configuration but did not the area, which mostly remained constant during the past 35 Kyrs. Active faults mostly affected the FdP playa-lake (its flooded area). As reviewer #1 stated, there were a misleading of the concept of FdP watershed and FdP playa-lake that has been solved in the new version of the MS. Moreover, in order to make it clearer, we have included that: "Although the watershed geometry could have changed, the FdP watershed area probably remained constant."**

La Nava playa-lake is considered as part of the AFS before dried up. It currently behaves as a recharge playa-lake, then it forms part of the FdP watershed. We have included in the current MS that: "Consequently, La Nava playa-lake is currently a recharge system linked to the FdP playa-lake."

Another line of evidence for changes in the FdP flooded area is the occurrence of a transition zone between fresher and more saline water at 1-2 m deep. But how the 1-2 m deep transition zone could be stable for thousands of years?.

Answer: **We acknowledge the reviewer's question. It is true that salt lake systems with large variations in chemical and stable isotopic composition and complex flow systems are not yet well understood. In addition, hydrogeochemical modelling approaches regarding brine evolution have also been poorly addressed in the literature. Anyhow, there are a few studies made in FdP playa lake, mainly from the last decade, that focused in this matter (e.g. Montalban et al., 2017; Heredia et al., 2010; Kohfahl et al., 2008). Tritium analysis of groundwater yielded high concentrations within the Miocene aquifer indicating ground-water ages younger than 50 years which points to comparatively fast ground-water flow at a greater distance from the lake. By contrast, brine samples taken from the lake sediments yielded tritium ages of more than 50 years and indicate longer residence times due to low hydraulic conductivities of lacustrine sediments (Rodríguez-Rodríguez et al., 2005). This is a key aspect of FdF hydrogeological system. Extremely low hydraulic conductivities below the lake implies very slow groundwater fluxes. On the other hand, electric tomography profiles for the location and characterization of the brines below and around the playa lake carried out by Ruiz et al. (2006) yielded elevated conductivities reflecting the presence of salt or saltwater up to a maximum depth of 100 m in the northern part below the centre of the lake. Mapping of the uppermost meters in the basin north of the lake shore indicates that the former lake extended about 3 km further north (Kohfahl et al., 2008). So the salt brine below the playa lake and consequently the interface with fresh groundwater is expected to remain stable during thousand years, even if the playa-lake displace its depocenter, as is the case in FdP. We included it in the new version of the MS: "…and it remains during thousand years once a playa-lake dries up".**

Heredia, J., García de Domingo, A., Ruiz, J. M., & Araguás, L. (2010). Fuente de Piedra Lagoon (Málaga, Spain): a deep Karstic flow discharge point of a regional hydrogeological system. Advances in research in Karst media, 231-236.

Kohfahl, C., Rodriguez, M., Fenk, C., Menz, C., Benavente, J., Hubberten, H., ... & Pekdeger, A. (2008). Characterising flow regime and interrelation between surface-water and ground-water in the Fuente de Piedra salt lake basin by means of stable isotopes, hydrogeochemical and hydraulic data. Journal of Hydrology, 351(1-2), 170-187.

Montalván, F. J., Heredia, J., Ruiz, J. M., Pardo-Igúzquiza, E., de Domingo, A. G., & Elorza, F. J. (2017). Hydrochemical and isotopes studies in a hypersaline wetland to define the hydrogeological conceptual model: Fuente de Piedra Lake (Malaga, Spain). Science of the Total Environment, 576, 335-346.

Rodríguez-Rodríguez, M., Benavente, J., & Moral, F. (2005). High density ground-water flow, major-ion chemistry and field experiments in a closed basin: Fuente de Piedra Playa Lake (Spain). American Journal of Environmental Sciences, 1(2), 164-171.

Ruiz, J. M., Rubio, F. M., Ibarra, P., García de Domingo, A., Heredia, J., & Araguas, L. (2006). Contribución de la tomografía eléctrica en la caracterización del sistema hidrogeológico de la laguna de Fuente de Piedra (Málaga)[Contribution of electrical tomography in the characterization of the hydrogeologic system of the lagoon of Fuente de Piedra (Málaga)]. Las aguas subterráneas en los países mediterráneos, 1, 353-358.

Tectonics.

Answer: **Active tectonics plays a crucial role on the FdP playa-lake evolution, then we tried to improve this relevant issue.**

One of the aims of the paper is to examine the role of Quaternary activity of active faults. However, there is no direct information of evidence for Late Pleistocene or Holocene faults activity (La Nava and Las Latas).

Answer: **Both Las Latas and La Nava faults affect Pliocene sediments (see results section). Moreover, earthquakes in this area are common, since it is close to these fault zones. The focal mechanisms of these earthquakes are also compatible with their kinematics; then we discuss that both faults are probably active during the Quaternary. In addition, the fault kinematics are compatible with the FdP playa-lake evolution. Now, we have discussed in more detail the age of both faults in the discussion section. We have added an additional reference that deals with this issue: "Indeed, both Las Latas and La Nava faults affect Pliocene sediments. The location of earthquakes and focal mechanisms are compatible with their kinematics (Jiménez-Bonilla et al., 2024). Consequently, both faults were probably active during the Quaternary."**

Although there are several references to tectonic activity of the Humilladero transversal zone during the last 30 ka, it would be better to include a paragraph stating what it is known about recent (< 30 ka) activity. The La Nava and Las Latas are active structures and there are references (Jiménez Bonilla et al,. 2015, 2023) to recent earthquakes, and geomorphological changes. Are there any dating of major activity related to FdP basin inception (Line 425) or evolution?. A general tectonic framework should also be included in a final figure comparing the lake level reconstruction based on the hydrological model, the sediment sequences, and local paleoclimate reconstruction.

Answer: **Unfortunately, there is not information about the tectonic activity of the Humilladero transverse zone nor the La Nava and Las Latas faults. This is an interesting topic that may be investigated in the future. In the last figure, we have included the plausible tectonic activity of these faults and their role on the FdP playa-lake evolution.**

Depositional evolution

The age models of both lake sequences are of low resolution and with large uncertainties. The long, littoral core has many reversals, and many dates are too old for their stratigraphic location.

In the central core, sediments at about 0.7 m below the playa-lake floor are 34±1.5 kyrs, the age of the sediments in the central basin is older than 48 kyrs and the bottom sediments could be as old as 98 kyrs (2012-PL1; Figs. 3A and 4B), but the age of the upper 70 cm is unknown. Both age models do not preclude the presence of erosive hiati. These are the best available age models for the sequences, but the reconstructed lake level time series should be taken with caution, and the comparison with the hydrological model output has to include the uncertainties. Could these large changes in sedimentation rates and/or depositional evolution between the southern, central and northern areas suggest that the FdP basin is actually composed of "independent" subbasins with varied depositional, hydrological and tectonic evolution?. If so, could the northern subbasin have had a different paleohydrological and lake level evolution during the Pleistocene, accounting for the lake deposits at 15 m above lake level?. May be the available data do not allow to discard some of these hypotheses, but it would be worth discussing them in the manuscript.

Answer: **This is an interesting question, and the FdP playa-lake could have splitted into separate flooded areas during its evolution at short periods of time. However, the presence of a flat topography at the main current FdP playa-lake and others outcrops that we consider part of the old FdP playa-lake makes it difficult: The La Nava playa-lake shows a really flat surface, but uplifted. The NE edge of FdP playa-lake also shows a flat topography but tilted towards the S and connected with the main FdP playa-lake body without any umbral. Nevertheless, we cannot completely discard the possibility of the formation of subbasins during the FdP evolution, then we added in the new version of the manuscript: "Alternatively, it can not be ruled out that the FdP playa-lake splitted in some subbasins during its evolution. It could also explain the little resemblance between 2012PL1 and 2012-PL2 (Figs. 5 and 6).".**

The lake level evolution is mostly based on gypsum crystal morphology of the long core (Line 310 and Figure 6). "Detrital gypsum" is a common occurrence in shallow playa lakes affected by wind erosion and frequent changes in lake level. The source area of the detrital gypsum in the southern areas could have been the same southern areas and also be the central zone. Are there any possible inferences of lake level evolution for the central core using the same criteria?. Would the 20-120 cm interval with carbonate muds and abundant prismatic gypsum crystals represent an older period of relatively higher lake levels?. What would be the estimated age of this humid period?, 40 – 60 ka ?(Fig 6) (Obert et al., 2022) ?.

Answer: **Thank you because this issue makes us to think more about the possible first stages of the FdP playa-lake. As we mentioned in the discussion, the FdP playa-lake inception was probably earlier than 35 kyrs, but we only focused on the last 35 kyrs. The existence of an older wet period could explain some parts of the described sedimentary sequences.**

There is no further information and discussion about the lacustrine terraces found by Höbig et al. (2016) at about 15 m above current lake level at the NE margin. The lacustrine terraces occurring about 10 m about lake level in the southern margin are re-interpreted as Pliocene sandstone (Line 395). As this is a significant piece of evidence for paleohydrological reconstructions, I would expand this section, with some more detailed sedimentological, compositional and depositional information.

Answer: **To the NE margin, we interpreted the "lake terraces" of Höbig et al. (2016) as "lake sediments", included in the Fig. 3 and in our results section. To make it clearer, we have better explained it in the discussion including: "In contrast, to the NE of the current FdP playa-lake, these deposits are dark soils with a flat topography which correspond with old lake deposits (Fig. 3)." In contrast, the sediments of the S margin of the playa-lake are not lake deposits, playa-lakes are not high energy environments to generate conglomerates nor sandstones within its sedimentary register. In the S margin, we only observed sandstones and conglomerates whose clasts come from more than 50 km far the playa-lake, out of the current FdP endoreic watershed. Consequently, they are not lake deposits. We have explained it better in the current MS version adding: "Moreover, these conglomerates and sandstones are made up of clasts from the Alboran domain, which is**

currently out of the FdP endoreic watershed. Then, these sediments were deposited before the FdP watershed inception."

The title reflect the main aims of the paper but it could be rephrased as "The role of Neotectonics and climate variability on Late-Quaternary hydrological evolution of Fuente de Piedra playa-lake (southern Iberia)".

Answer: **We changed the title of the MS into: "The role of neotectonics and climate variability on the Pleistocene-Holocene hydrological evolution of the Fuente de Piedra playa-lake (southern Iberia)" due to the importance of neotectonics in the discussion.**

Please let us know if any more corrections or changes are necessary.

Yours sincerely,

Dr. Alejandro Jiménez Bonilla on behalf of the co-authors