

Reply to the comments of reviewer n.2

PLEASE NOTE THAT THE REVIEWER'S WORDS ARE IN RED COLOR AND OUR REPLY IS IN BLACK COLOR.

The research conducted by Marini et al. presents a novel interpretation of four decades of data from the Solfatara geochemical database, utilizing new geoindicators and aiming to offer potential predictions of future scenarios. The subject matter is of significant scientific relevance, particularly as the Solfatara magmatic-hydraulic system holds considerable interest, not only for the scientific community engaged in the study of this system, but also due to the concerns regarding the potential evolution of the current bradyseism towards eruptive scenarios, which may have substantial societal implications for the population residing in its vicinity. However, despite the relevance of the topic, I feel that the paper in its current state is not ready for publication, and that some concerns about the manuscript should be addressed before publication.

As written in our paper, *"The reason that pushed us to write this paper is to provide a contribution to the discussion animating, in this period, the international scientific community on the possible evolution of the unrest episode currently affecting the Campi Flegrei. The mitigation of the volcanic hazard in the Campi Flegrei is not a local issue because worldwide volcanologists look at it as an analogue of similar volcanic systems (see Chapter 11 of Marini et al., 2022)."* We are aware of the *"substantial societal implications for the population residing in its vicinity"*, as written by the reviewer. In fact, our paper ends with the following considerations on societal implications: *"If we want 500,000 people to continue to live in the Campi Flegrei area affected by the bradyseism without the sword of Damocles of a hydrothermal event, it is necessary to find an appropriate solution such as to guarantee the seismic stability of a large number of buildings, in the order of 100,000, or to manage the bradyseism by zeroing the inflation of the intermediate reservoir depressurizing it. The first approach requires an investment without any economic return and does not mitigate the hazard posed by hydrothermal events. The second strategy provides a permanent solution to the problem in that it cancels the hazard posed by hydrothermal events (Lima et al. 2024). It requires a considerable initial investment to drill a suitable number of geothermal wells to ~4 km depth and to construct both a geothermal power plant and a mineral recovery plant. However, it provides a considerable economic return, thanks to the exploitation of geothermal energy for electrical production and the recovery of raw materials of utmost interest such as lithium. The feasibility of geothermal exploitation was proven by AGIP-ENEL activities carried out in the '70s and '80s (see above). The obstacles that existed at that time and caused the end of geothermal exploration no longer exist today, thanks to the improvements in drilling materials and technologies, as demonstrated by ongoing drilling activities in several supercritical geothermal systems (e.g., Reinsch et al., 2017)."*

Summing up, we are aligned with the reviewer words.

Nevertheless, in the annotated manuscript, the reviewer wrote the following sentences concerning our considerations on the societal implications reported above: *"I do not question the accuracy or validity of these statements, but note that there is no discussion of these issues in the main text, and here in the conclusion they seem off topic. That arguments should be considered and discussed in a dedicated section of the paper where the authors can provide the necessary data, cost analyses and other relevant information to support the claims made in the conclusion. Alternatively, it is recommended that these statements be removed from the concluding section."*

Considerations on the need to drill and exploit geothermal energy, similar to our considerations, were meanwhile published by Lima, A., Bodnar, R. J., De Vivo, B., Spera, F. J., Belkin, H. E.: The "breathing" Earth (la terra che respira) at Solfatara-Pisciarelli (Campi Flegrei, southern Italy) during 2005-2024: Nature's way of attenuating the effects of bradyseism through gradual and episodic release of subsurface pressure. *American Mineralogist*, in press, <https://doi.org/10.2138/am-2024-9516> 2024, 2024. The main difference between our paper and that of Lima et al. (2024) is that they proposed to drill geothermal wells

to 5 km depth or more whereas, in our opinion, it is useless to drill so deep, because the target of geothermal drilling is the 2.7 to 4.0 km deep intermediate reservoir. No cost analysis was presented by Lima et al. (2024). Therefore, for the principle of *par condicio competitorum*, we would be inclined to maintain our considerations on societal implications in our paper. If we are asked to review our manuscript, we would prefer to move these considerations from the concluding section to section “4.8 Possible future scenarios”. In fact, these societal implications are directly linked to the hydrothermal eruption possible scenario.

In the following, I would like to point out two reasons I consider to be of great importance, and which should be reconsidered by the authors before a possible publication. Furthermore, in an attached file, I have integrated the comments and suggestions next to the relative text which are aimed at improving the readability of the text and the completeness of the information according to my personal vision.

We thank the reviewer for the constructive comments and suggestions reported in the annotated manuscript. If we are asked to review our manuscript, we are ready to change our paper according to all the reviewer’s comments and suggestions apart from that on the societal implications (see above) and Figures 8c and 8b. The time scale of these two figures, referring to seismic events, begin with 2005 because no data on seismic events are reported on the INGV website (<https://terremoti.ov.ingv.it/gossip/flegrei/years.html>) before 2005, apart from 1983 and 1984. If needed, we will try to ameliorate Figure 8. We are sure that our manuscript will be improved thanks to the appreciated comments and suggestions of the reviewer.

In summary, the two most important aspects of the manuscript I believe should be reviewed in order to improve the quality of the paper before its possible publication are as follows:

1. The heart of the work consists in the reinterpretation of geochemical data based on the use of new geoindicators. Unfortunately, the text does not contain the information necessary to understand and interpret these geoindicators, which, as the paper is set up, must be well understood to ascertain the fields of applicability and potential limitations. This makes the paper not immediately understandable nor directly usable by the scientific community (after reading this document, can the use of these new geo-indicators be replicated in other cases?), unless one looks for the source, however this is contained in a book that precludes easy acquisition for many. I myself have not been able to find it, as I explained in the attached file. However, the authors of this manuscript are also the authors of the monograph; therefore, it is my opinion that they could easily integrate the text with a specific section describing the new geoindicators, which would certainly enhance the text. As a side effect, I was only partially able to follow the exchange between the first reviewer and the authors, due to the asymmetry of information caused by my lack of knowledge of the content of the monograph cited.

We agree with the reviewer on this point and we are ready to expand considerably the section Method of our paper, in order to provide the information needed to understand the new gas-geoindicators of Marini et al. (2022), including their applicability and limitations. It is true that, in our paper, the considerations on these new gas-geoindicators are limited to a minimum, but we thought that the book of Marini et al. (2022) was part of the scientific literature and was easily acquirable as any scientific paper. We are sorry for the difficulties encountered by the reviewer and we are ready to email to the reviewer a copy of our e-book.

1. Another significant concern relates to the capability to predict specific scenarios following the analysis and model interpretation. I acknowledge that the term "prediction" can have various meanings; however, in scientific literature, it is generally accepted to convey the notion of "the expectation of an occurrence under certain conditions". Typically, this expectation is quantified and qualified through numerical analysis (statistical or probabilistic), which lends credibility to the process of predicting future events or outcomes. Prediction can be viewed as part of hypothesis testing, where one formulates predictions as components of hypotheses. These predictions can then be empirically tested through experiments or observations to confirm or refute the

hypotheses. However, this concept is not clearly articulated in the text. Instead, the authors present reasonable scenarios that could evolve in different directions, potentially even oppositely, without providing any arguments or analyses to support specific predictions. The text offers only a description of various possible scenarios, lacking a basis for making predictions. In my opinion, this aspect of the paper needs to be reconsidered, given the significant importance of the ability to make predictions, especially for local authorities responsible for managing risk in a densely populated area like Campi Flegrei. Therefore, I suggest that the authors revise the use of the term "prediction" from the title onward, modifying the text accordingly or providing sufficient justification to support the possibility of predicting potential risk scenarios.

We have no problem to change the terminology. We are ready to use the term inference instead of prediction, the verb to infer instead of to predict, and so on.

I hope that the critical reading of the manuscript that I propose in its current state can be a constructive stimulus for the authors, regardless of the outcome of the publication.

Again, we thank the reviewer for the constructive comments and suggestions, irrespective of the fate of our paper.

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