Stathis C. Stiros (Referee)

Interactive comment on "The millennium old hydrogeology textbook "The Extraction of Hidden Waters" by the Persian mathematician and engineer Abubakr Mohammad Karaji (c. 953–c. 1029)" by Behzad Ataie-Ashtiani and Craig T. Simmons

The manuscript by Ataie-Ashtiani and Simmons discuss the novelty and importance of the 11c. book of Al Karaji "Extraction of hidden waters" for the exploitation of subsurface waters in Medieval times using the qanat technology. This is an important, poorly known interdisciplinary topic covering Hydrology, Geotechnical Engineering and Geodesy, with various important implications and suitable for the Special Volume of HESS on the 'History of Hydrology'.

Response: We appreciate the positive appraisal by Professor Stiros and the detailed and helpful comments that will be addressed in the following response.

The manuscript, however, has two main problems, which call for major revision, mainly focusing on the need for a more critical and technical approach. A) A first problem is that the manuscript is describing the work and personality of Al Karaji from a rather narrow point of view. His contribution cannot and should not be underestimated, but the context and possible background of his work should be noticed. A1) Some pioneers in the study of qanats such as Wulff and English, cited by the authors, notice a "Book on qanats", written about 100 years before Al Karaji and which covers at least some aspects of Al Karaji's book. A2) Persian engineering during the Abbasid period described by Al Karaji is likely to summarize a knowledge and experience which was both produced in Persia and imported from other regions. Clearly, early engineers in Persia and the surrounding area had developed a technology for the construction of the first qanats in favourable rock conditions (what can be currently classified as soft soils), probably since 1000BC (and not since 3000BC, as marked in line 89), but at the same period there have been impressive engineering works in the regions covered by modern Greece (Mycenean era, before 1000BC) and modern Italy (circa 700BC, Etruscans) (see for example Angelakis et al, 2003). Furthermore, Eupalinus had constructed in Samos Island, Aegean Sea, a 1000m long tunnel from two openings only, with a second, qanat-type tunnel beneath it through both unstable and hard rock (see Kienast, 1995); this testifies to an ancient technology and science which have probably influenced later periods, including Al Karaji (cf. Lewis, 2001). The Persian expansion to Egypt during the Achaemenid period was most probably facilitated by the adaptation of the qanat technology to Egypt, but Persians probably benefited from the knowledge of surface waters by ancient Egyptians who had developed specific metrological techniques ("Nilometers"). Apart from a mutual transfer of technology in hydrological engineering between ancient Persia and adjacent regions, at a later stage, there might have been also a transfer of Roman water technology (for example, Grewe, 1998), summarized by Vitruvius, the work of which was possibly known to Persian intellectuals.

Response: We agree with the reviewer's comment. We had tried to implicitly highlight that Karaji was standing on the foundations of knowledge that may have been laid down by the people who lived before him. For example, in L16 we mentioned: "Although some of the ideas may have been presented elsewhere,..." and in L49-55 we wrote: " Karaji lived in Baghdad under the Abbasid rulers. We anticipate that he would have been a direct beneficiary of the translation movement. This initiative was begun under the second Caliph Al-Mansur and continuing through to the seventh Caliph Al-Ma'mun and saw a large amount of significant scientific, religious and other literature translated into Arabic for scholars to use. At this time,

Baghdad was one of the world's greatest places of learning and knowledge. It hosted some of the world's best libraries. It was a vibrant place for scholarly activity and scientific discovery. The Middle East became the centre of intellectual thought instead of Europe."

The focus and purpose of this essay was on Karaji's book and contributions, without any attempt to downgrade any other possible contributions from others. It is not a comparative analysis. L34-37: "We believe that Karaji's contributions in hydrology and hydrogeology are significant and should be remembered and revisited in this Hydrology and Earth System Sciences special issue on the 'History of Hydrology'. In this essay, we revisit this book and provide an English translation of the pieces from the book that crucially offer pioneering ideas in hydrogeology and in general for engineering projects". Therefore, it is beyond the scope of this easy to provide an exact historical audit for the contributions of ancient Greeks, Chinese, Indians, and Persians and others in Hydrology and hydrogeology.

B) A second point noticed in Stiros (2006) is that Al Karaji (and all other ancient writers) on one hand was subject to strict limitations in publicization of critical technical information, which was limited to muqannis, of specific guild-type groups working on qanats till the sub-modern era; this makes ancient books different from modern technical manuals. On the other hand, Al Karaji book reveals that he had the SENSE of engineering (for example concerning his understanding of accuracies) and he was most probably aware of critical details of the construction and exploitation of qanats. In this framework, his book included several figures, in some analogy to the book of Agricola, and this was rare in the ancient world.

These figures (which are currently freely accessible) are the most important and less well understood point of his work (only some have been commended by Lewis 2001), and they deserve some explanation. I am afraid that in its present form, the manuscript does not permit to the average reader to understand what these figures mean and the techniques used in antiquity to construct aqueducts. I believe that this problem can be easily overpassed, adding some explanations for each figure. Such explanations need not be very technical and detailed, as for example in Stiros (2012) for the leveling of qanats or in Lewis (2001), but it is enough to add next to each ancient figure an explanatory graph and a short text to summarize their significance. For example, in figure 9 for the alignment of the tunnel, it is suggested to use some shading for the rock, to mark the shaft and the tunnel axis (I guess marked with letters in the original figure), to explain some symbols used and also provide an order of magnitude of the scale indicated. For some figures, the comments of Lewis 2001 on Al Karaji (especially pages 298-302) will be very helpful. These changes will lead to a useful and well documented article, suitable for the Special Issue of HESS on the History of Hydrology.

Response: This is animportant observation by Prof. Stiros. We have also mentioned atL112-116: "The titles of the book sections provide a fascinating insight into the wide range of topics that were covered in the book. It is amazing that the book not only covers the conceptual and technical aspects as well as construction guides, it also provides guidelines for maintenance and even advice on how to deliver and consign the project when the development and construction is over. It even touches on important social aspects such as religious regulations. The book is like a construction and maintenance manual for a modern engineering project!" and "L251-254: Beyond the specific topic of Karaji's book on the extraction of hidden waters, the comprehensive content, details and topics that he has covered in the book are very impressive for engineering construction project management. This important point has not been noted before, to the best of our knowledge."

Based on the reviewer's comment we have added the following in the revised version of this essay:

"Lewis (2001), who explored the history of surveying instruments of Greece and Romans, referred to Karaji's book and his contributions in procedures and inventive instruments for levelling and sighting in surveying engineering. Karaji's ideas in surveying revealed his sense of engineering concerning an understanding of accuracies and awareness of essential elements of the construction and exploitation of qanats (Stiros, 2006)."

Also, further explanations have been added in the figure captions to the extent that it is relevant and within the scope of this essay.

Anonymous Referee #2

Interactive comment on "The millennium old hydrogeology textbook "The Extraction of Hidden Waters" by the Persian mathematician and engineer Abubakr Mohammad Karaji (c. 953–c. 1029)" by Behzad Ataie-Ashtiani and Craig T. Simmons

L21-22: the texts (انباط المياء الخفيه) and (ابوبكر محمد بن الحسن الكرجى) are Arabic and not Persian

Response: The reviewer's comment is correct and has been changed in the revised version of the manuscript. As Karaji was originally Persian (see Girogio Levi Della Vida, 1934) and that the Arabic and Persian alphabet are similar, we had used the term Persian in the early version. This has now been corrected.

L54-55: the phrase "Instead of Europe" is redundant. I suggest to neglect this phrase.

Response: Agreed and modified.

L74: what is the reference for this sentence" Karaji returned to his homeland wrote the book". Please mention the evidence related to this allegation.

Response: Karaji is considered to be born in Persia (e.g., Girogio Levi Della Vida, 1934; Xadiv Jam, 1966; Nadji and Voigt, 1972). His return to Persia when he wrote the book has been mentioned in Nadji and Voigt (1972) and Lewis (2001). To the best of our knowledge, this is correct. These references have been added to the modified version.

L254: The authors are requested to develop the idea that claims "the book is the first book on engineering construction management". It needs more proofs and analysis

Response: As it was mentioned in the manuscript this is a speculation by authors as L112-116: "The titles of the book sections provide a fascinating insight into the wide range of topics that were covered in the book. It is amazing that the book not only covers the conceptual and technical aspects as well as construction guides, it also provides guidelines for maintenance and even advice on how to deliver and consign the project when the development and construction is over. It even touches on important social aspects such as religious regulations. The book is like a construction and maintenance manual for a modern engineering project!" and L251-254: "Beyond the specific topic of Karaji's book on the extraction of hidden waters, the comprehensive content, details and topics that he has covered in the book are very impressive for engineering construction project management. This important point has not been noted before, to the best of our knowledge."

We have relaxed our assertion about the book being "the first" of its kind. We have changed "the book is the first book on engineering construction management" to "the book is among the earliest known texts on engineering construction management".

S. Majid Hassanizadeh (Referee)

Interactive comment on "The millennium old hydrogeology textbook "The Extraction of Hidden Waters" by the Persian mathematician and engineer Abubakr Mohammad Karaji (c. 953–c. 1029)" by Behzad Ataie-Ashtiani and Craig T. Simmons

I enjoyed reading this manuscript. It gives a thorough description of Karaji's work, its scientific as well as historical significance, and its practical value. It is definitely a valuable addition to this issue of HESS. I believe the manuscript needs to be improved as some statements are not accurate (please see below for examples).

Response: We appreciate the positive appraisal of Prof Hassanizadeh and the useful comments that will be addressed in the following response.

Also, the text needs improvement; I have provided quite a few suggestions in the annotated pdf file. - I would like to suggest including a figure showing a sketch of a qanat and its various elements. This will be beneficial for the reader, and will it easier for the author when explain a qanat (in subsection 1.2, lines 83-90).

Response: With thanks we have considered all the annotated comments on the Pdf file and have mostly implemented them. We have avoided providing a sketch of qanat as we speculate it is known to HESS readers and it can be found easily by any internet search.

The description of figures provided at the end of the manuscript is somewhat superficial and does not really help the reader to understand the figures and their importance. It is also not possible for most readers to read the Arabic text accompanying figures. Aren't these pages translated into English by Schade? If they are, I suggest the authors provide give copies of pages from Schade's book instead of the original Arabic pages.

Response: As this is essay is an historical account of the Karaji's contributions, we suppose the original figures and pictures of the original book would be noteworthy for the readers. We have provided the essence of the relevant text regarding the figures in the captions to the extent that is matched to the scope and aim of the essay.

Qanats were not in use only in arid areas of the Iran, as suggested in line 77. They were in use everywhere in Iran, including mountainous regions in northern (except for the Caspian Sea coast) and western parts of Iran, with plenty of water.

Response: We have not stated that qanats were only used in the arid areas. The text is "we may speculate that the topic was of great practical interest in the arid area of the Persia plateau." Although there are qanats in the mountainous regions (e.g. in Tehran), the major development and application of this system is in arid and semi-arid regions.

In referring to the qanat tunnel, various words have been used (aqueduct, channel, tunnel) without being clear to the reader that they are all the same thing. I suggest using one word (e.g., tunnel) in all cases. In particular, I suggest avoiding the use of aqueduct, as it is too closely associated with the Roman aqueducts.

Response: Agreed and modified.

Actually, the qanat technology went to Northern Africa before going to Spain. In other words, one could say: “A second major diffusion of Qanat technology occurred with the conquests of Islam into Northern Africa, the peninsular Spain, and the Canary Islands.” Also, it is worth mentioning that qanats are found in India as Southerly as Kerala and in Chinese Turkmenistan.

Response: Agreed and modified.

I am not sure the procedure described in lines 173-178 has been really an effective way of water filtration (as suggested in line 177). For water to lose its salinity and heaviness, due to passage through neat ground soil [Isn’t this double? ground soil? Why not just soil?], an ion exchange process must occur. So, it must be a soil with some special characteristics. Also, I can’t see how water would lose a portion of its salinity and heaviness when leaking from a new pot! Perhaps the authors should elaborate on the potential of this procedure for reducing salinity.

Response: The major part of the provided lines, the quoted part in italics, are the translations from Karaji’s book. In the last sentences we have emphasized that this based on the available knowledge and apparatus of Karai’s time: “The treatment Karaji outlined is essentially a water filtration process based on the knowledge and apparatus of the time.”

I do not think the presentation in lines 212-220, linking the laws about water rights and safe distances between wells and qanats to Islamic laws, the script, and the prophet Muhammad’s practice, is justified. There existed wells and qanats in Iran before Islam and cities and villages had laws and customs ruling such things. Also, I wonder whether exact numbers given by Karaji (lines 214 and 215) can be found in Islamic records. Moreover, I don’t see the value of linking Karaj’s writings to Islamic laws. If this is needed, I think a more detailed investigation with references, in order to document such a link, should be provided.

Response: The issue protection boundary of wells and qanats based on religious laws was explained by Karaji in his book from page 67 to 79 (Xadiv Jam, 1966). In his explanations he referred to the opinions of Islamic law scholars’ (e.g, Hassan Basri, Abu Yousef, Abu Hanifeh) who had referred to prophet Muhammad’s practices and sayings.

We have added this explanation to the revised manuscript.

Protection zone of wells and qanats is a term used in relation to contamination (i.e. protection from pollution) and not to the use and extraction of water (which is the context in line 212). I think the proper terms here are ownership limits and well boundaries.

Response: Protection zone has been used here in a more general sense that the existing wells and qanats would not be influenced by establishing a new well.

Please also note the supplement to this comment:

https://www.hydrol-earth-syst-sci-discuss.net/hess-2019-407/hess-2019-407-RC3-

supplement.pdf.

Response: We appreciate these comments. The comments were considered and modified.