

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 essay 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 an important observation by Prof. Stiros. We have also mentioned at 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."

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.