

## Joeri van Engelen

### **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**

First of all, I think Ataie-Ashtiani and Simmons cover a very exciting and yet overlooked book, that definitely deserves more attention. Historical notes on non-European works that cover hydrology are rare, even though dismissing these leads to a gap in scientific history. Limited scientific progress was made in Europe between the fall of the Roman Empire and the Renaissance, as far as I am aware of. Many ancient civilizations outside Europe existed that carefully managed their water and must have had an understanding of hydrology.

The paper starts with a concise background on Karaji’s “The Extraction of Hidden Waters”, providing context of Karaji’s time and place, other important findings of Karaji, and possible motivations for the book. Following this, several important parts of Karaji’s book are summed: The description of Qanats, the pragmatic topics the book covers, followed by a selection of quotes that highlight Karaji’s understanding of hydrology and a comparison to what later authors wrote.

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

I am under the impression that the authors have thoroughly read later European works, but I think they have missed a Roman work. Vitruvius wrote a series of ten books called “de Architectura” (on Architecture). The eighth book of this series covers water, in which he discusses several topics that were also discussed in The Extraction of Hidden Waters. Even though I personally share the authors’ excitement on the importance of Karaji’s work, I think some more care should be taken with claims that something is the “first” or “earliest”.

First of all, it is stated that Karaji’s “The Extraction of Hidden Waters” is the oldest textbook on hydrology (line 254). This of course depends on when a textbook covers a topic x thoroughly enough to be called “a book on x”. I think one important criterium should be a discussion of the hydrological cycle, as Karaji did. Vitruvius discusses the hydrological cycle in his chapter “Rainwater”:

“...And rainfall is not abundant in the plains, but rather on the mountains or close to mountains, for the reason that the vapour which is set in motion at sunrise in the morning, leaves the earth, and drives the air before it through the heaven in whatever direction it inclines; then, when once in motion, it has currents of air rushing after it, on account of the void which it leaves behind. ... Wherever the winds carry the vapour which rolls in masses from springs, rivers, marshes, and the sea, it is brought together by the heat of the sun, drawn off, and carried upward in the form of clouds; then these clouds are supported by the current of air until they come to mountains, where they are broken up from the shock of the collision and the gales, turn into water on account of their own fullness and weight, and in that form are dispersed upon the earth.” (Vitr. 8.2.1 and 8.2.2 translated by Milford, 1914).

**Response:** We would like to emphasize that the objective of this essay was to celebrate Karaji’s book and contributions, without any attempt to downgrade any other possible contributions from others. It is not a detailed comparative analysis. For example, in L16 we mentioned: “Although some of the ideas may have been presented elsewhere,...”. Therefore, we do not claim that all the ideas in this book were presented for the first time by

Karaji. We have claimed that “L16:..., this is the first time that a whole book was focused on different aspects of hydrology and hydrogeology.”. To the best of our knowledge this is a valid claim.

In Vitruvius’s de Architectura or The Ten Books on Architecture, although there are chapters/books (in particular Book VIII-pages 225 to 251 in Morgan’s translation) regarding water and hydrology, the de Architectura is essentially about Architecture. We understand the commenter’s point on the use of the “first”. We have modified it to “ ..., to the best of our knowledge, this is the first time that a whole book was focused on different aspects of hydrology and hydrogeology”. We have relaxed our assertion about the book being “the first” of its kind. We have changed "the book is the first book on ..." to "the book is among the earliest known texts on ... ".

Furthermore, the authors suggest in lines 229-230 that Karaji’s work may show the earliest (written) conception of hydraulic conductivity. An earlier potential of understanding of hydraulic conductivity can be found in Vitruvius:

*“Searchers for water must also study the nature of different localities; for those in which it is found are well defined. In clay the supply is poor, meagre, and at no great depth. It will not have the best taste. In fine gravel the supply is also poor, but it will be found at a greater depth. It will be muddy and not sweet. In black earth some slight drippings and drops are found that gather from the storms of winter and settle down in compact, hard places. They have the best taste. Among pebbles the veins found are moderate, and not to be depended upon. These, too, are extremely sweet. In coarse grained gravel and carbuncular sand the supply is surer and more lasting, and it has a good taste. In red tufa it is copious and good, if it does not run down through the fissures and escape.” (Vitr. 8.1.2 translated by Milford, 1914).*

**Response:** As seen, our conjecture about the Karaji’s earliest conceptions of hydraulic conductivity based on his conception of protection area. In L219-231. We wrote: “Next, Karaji defined protection limits based on his knowledge and consideration of differing soil types. “*The protection areas of Qanat in hard soils is less than that for loose soils.*” [Translated from Page 74: Xadiv Jam, 1966]. Karaji understands that wells placed in the more permeable material (the loose soils) require a greater area or size for the groundwater protection zone around it compared to that in the less permeable material (the hard soils). Groundwater protection or buffer zones are based on the very same principle today – a principle that Karaji conceived a thousand years ago. We speculate that what Karaji mentioned here is related to his intuitive understanding of the ease of water flow in loose soils compared to that in hard soils. It is possible that Karaji understood that water flowed more easily through loose soils than it did through hard soils – leading to a concomitant increase in the size of the protection zone for a well in the more permeable material (the loose materials). This may be some of the very earliest documented insights into the rates and ease of groundwater flow through different geologic materials – earliest conceptions of what we would call hydraulic conductivity today. They are also among the earliest known documented conceptions of modern-day hydrogeology.”

Finally, just like in The Extraction of Hidden Waters, several pragmatic aspects of water management in book 8 of De Architectura. Listing the chapter titles: How to find water; rainwater; various properties of different waters; tests of good water; levelling and levelling instruments; aqueducts, wells, and cisterns. Furthermore, book 10 of De Architectura covers the construction and workings of several contraptions that are relevant to water management: engines for raising water; water wheels and water mills; and the water screw. Therefore, Vitruvius approaches Karaji in the range of covered topics.

To conclude, I think it is very debatable whether *Extraction of Hidden Waters* is the first textbook on hydrology. I do however think it can be argued that it is the first known textbook on hydrogeology. In addition, Karaji seems to cover several topics that are not covered by Vitruvius: the construction of Qanats, maintenance guides, well protection zones, and a better understanding of how water flows through the subsurface. It therefore appears to me that the *Extraction of Hidden Waters* is a lot more complete than *De Architectura* book 8.

I encourage the authors to look into *De Architectura* and briefly compare it with *The Extraction of Hidden Waters*. An English translation of his book can be found here: <http://www.perseus.tufts.edu/hopper/text?doc=Perseus>

Furthermore there is also a paper that discusses the ancient Chinese notes on hydrogeology, that might be of interest to you as well:

Zhou, Y., Zwahlen, F. and Wang, Y.: The ancient Chinese notes on hydrogeology, *Hydrogeol. J.*, 19(5), 1103–1114, doi:10.1007/s10040-010-0682-1, 2011.

**Response:** To cover a complete historical description of the development of hydrology and to consider the contributions of different ancient states such as Chinese, Greeks, Persians (and others), and is beyond the objective and scope of this essay. We could not do this synthesis and comparative analysis justice in a brief summary. As mentioned, we are not aware of any other book before Karaji's book that was a whole book focused on different aspects of hydrology and hydrogeology. We agree with the commentator that it can be [argued that it is the first known textbook on hydrogeology](#). As noted earlier, we have modified the text to relax the notion of the first textbook to "..., to the best of our knowledge, this is the first time that a whole book was focused on different aspects of hydrology and hydrogeology".