Arabic sciences and philosophy, 31 (2021): 159-182
doi:10.1017/S0957423921000059

HYDRAULICS AND HYDROLOGY IN A PASSAGE OF THE *KITĀB AL-ĀṮĀR AL-BĀQIYA* BY AL-BĪRŪNĪ

MASSIMILIANO BORRONI
Università Ca' Foscari, Venezia, Italy
Email: massimiliano.borroni@unive.it

VLADIMIRO BOSELLI
Università degli Studi di Brescia, Italy
Email: v.boselli@unibs.it

Abstract. The authors translate and comment a digression from the *Kitāb al-āṯār al-bāqiya* on several hydraulic and hydrological subjects. The passage reveals al-Bīrūnī's understanding of fluvial regimes, water physical behaviour, and of a handful of peculiar natural phenomena. Al-Bīrūnī departs from a discussion of weather forecast and seasonal fluvial regimes of the Tigris, Euphrates, Oxus, and Nile. The main concern of al-Bīrūnī is to defend the principle that water moves only downwards in absence of external forces. In doing so, the Khwarazmian scientist touches on the origin of salinity of the seas, the functioning of syphons related hydraulic machines, and relates a report of an artificial phenomenon, that he dismisses as result of faulty observations, that could be recognised as a hydraulic jump. In addition, the passage contains much relevant information on al-Bīrūnī's understanding of the inhabitability of subequatorial regions, the possibility of the void, and the water cycle.

Résumé. Les auteurs traduisent et commentent un passage du *Kitāb al-āṯār al-bāqiya* concernant l'hydrologie. Ce passage révèle comment al-Bīrūnī comprenait les régimes fluviaux, le comportement physique de l'eau, et quelques phénomènes naturels spéciaux. Al-Bīrūnī ne se contente pas d'une discussion sur la prévision météorologique et les régimes fluviaux saisonniers du Tigre, de l'Euphrate, de l'Oxus et du Nile. Il défend surtout le principe qu'en l'absence de force externe, l'eau se meut vers le bas. Ce faisant, le savant du Khwarezm touche à l'origine de la salinité des mers et au fonctionnement des machines à syphon hydraulique, et il décrit un phénomène artificiel, qu'il rejette comme résultant d'observations erronées, mais qu'on pourrait reconnaître comme un cas de saut hydraulique. De plus, ce passage renseigne sur ce qu'al-Bīrūnī comprenait du caractère inhabitable des régions sub-équatoriales, de la possibilité du vide, et du cycle de l'eau.

1. INTRODUCTION

In the present article[1] we discuss a passage from the *Kitāb al-āṯār al-bāqiya*, the well-known first written work of Abū Rayḥān al-Bīrūnī

(362/973 – 440/1048 or 442/1050).[2] We rely on philological and hydrological notions to provide an improved translation[3] and commentary. In this passage, the Khwarazmian polymath digresses from the main subject matter of the *Āṯār*, i. e. calendars and chronology, to discuss a wide range of topics regarding water. In broad terms, the text deals with subjects in the field of hydrology and environmental hydraulics.[4] The entire passage is dictated by the urgency to state a general principle governing the behaviour of water, and the technical limitations that said principle imposes on engineering enterprises, a chief interest of al-Bīrūnī, who

[1] Massimiliano Borroni wrote the cultural and historical contextualisation, linguistic analysis, and translation, and carried out the final write-up. Vladimiro Boselli wrote the scientific and engineering discussions, the epistemological contextualisation and provided the figures in this article. The authors worked together on textual analysis. Borroni's contribution was made possible by the Centro di Ricerca Marco Polo – Centre for Global Europe-Asia Connections (Department of Asian and North African Studies, Ca' Foscari University of Venice).

[2] The details of al-Bīrūnī's life under the Ghaznavids are not entirely clear, and so is the date of his death. Boilot holds that he died after 442/1050, because al-Bīrūnī states in his last important work, the *Kitāb al-ṣaydala fī al-ṭibb*, that he was over 80 years old. Bosworth, following Karimov and Bulgakov, disagree and place the date of death at 440/1048. D. J. Boilot, "Al-Bīrūnī," in *Encyclopaedia of Islam*, 2nd ed. (Leiden: Brill, 1960-2005, quoted as EI2 from now on); Clifford Edmund Bosworth, "Bīrūnī, Abū Rayḥān," 1st section, "Life," in *Encyclopædia Iranica*, 2010, www.iranicaonline.org/articles/biruni-abu-rayhan-i-life.

[3] There is, indeed, a well-known English translation of the *Kitāb al-āṯār al-bāqiya* by Sachau. We felt that this passage needed an updated translation because of its technical content. Since Sachau's interest for the *Āṯār* was dictated mainly by philological, chronological, and historiographical reasons, his translation of this more technical – and at times slightly obscure – passage suffers from some rare inaccuracies and is at times not as clear as it could have been.

[4] Hydrology is that branch of science studying the movement, distribution and quality of water throughout the Earth including the hydrological cycle. Hydraulics is a branch of mechanics, continuum mechanics to be more precise, dealing with the mechanical properties of liquids, its topics applied to engineering problems to study pipe flow, reservoir design, pumps and channel behaviour. For a discussion of hydrology, hydraulics and broadly speaking scientific knowledge pertaining to water in the Arabo-Islamic tradition see Mohammed El-Faïz, *Les maîtres de l'eau: Histoire de l'hydraulique arabe* (Arles: Actes Sud, 2005), 94-100. For a discussion on the evidence for transmission of classical water technology to the early Islamic world see A. I. Wilson, "Classical water technology in the early Islamic world', in Ari Saastamoinen and Christer Bruun (ed.), *Technology, ideology, water: From Frontinus to the Renaissance and beyond*, papers from a conference at the Institutum Romanum Finlandiae, May 19-20, 2000 (Rome: Institutum Romanum Finlandiae, 2003), 115-41. On mechanical and civil engineering – both closely connected to water management – in the pre-modern Islamic civilisation see the relevant chapters in Ahmad Y. al-Hassan and Donald R. Hill, *Islamic technology: An illustrated history* (Cambridge University Press, UNESCO, 1986), 37-91.

saw science as a "problem solving activity."[5] The central statement that al-Bīrūnī puts forth in this passage is that water cannot rise above its point of origin. We will spend a few words on the context of this passage, before discussing the theses put forward by al-Bīrūnī and their relevance for our understanding of his methods.

2. CONTEXT OF THE DIGRESSION

Abū Rayḥān al-Bīrūnī, native of the suburbs of Kāṯ, which was then capital of Afrighid Khwarezm, is as well-known today as he was in his time for the variety of his learning and his empiricist approach. The subject of empiricism is ubiquitous in scholarly literature on any aspect of al-Bīrūnī work and life, and it even made its way into more popular literature, as the case of a UNESCO anthology dedicated to al-Bīrūnī testifies.[6] The passage discussed in this paper enlightens us on the nature of al-Bīrūnī's empiricism, which can be better understood in the context of the general agreement between rational inquiry and Islamic revelation recognised by Bausani as the hallmark of Bīrūnī's thought.[7] At the same time, this short text gives us a few clues to his understanding of climatic, hydrological and hydraulic phenomena at the time of the composition of the *Āṯār*.

In 338/998 al-Bīrūnī left the court of his first patron, the Samanid ruler Manṣūr, relocating in Jurjān at the dependence of the Ziyarid Sulṭān Qabūs.[8] In 390/1000 al-Bīrūnī dedicated the *Āṯār* (also known under the English title *The chronology of the ancient nations*) to him. The *Kitab al-āṯār al-bāqiya ᶜan al-qurūn al-ḫāliya*, which is a treatise

[5] A. L. Samian, "Virtues in al-Biruni's philosophy of science," in Anna-Teresa Tymieniecka (ed.), *Timing and temporality in Islamic philosophy and phenomenology of life* (Dordrecht: Springer, 2007), 268-69.

[6] Vv. Aa., "Al-Biruni: Miniature anthology, including many translated into English for the first time," *The UNESCO Courier: A window open on the world*, 1974.

[7] Bausani stressed that "for Bīrūnī science and the Qurᵓān agree, esoteric *maᶜrifa* and the Qurᵓān do not." Alessandro Bausani, "Bīrūnī between *scientia* and *sapientia*: Some remarks on Bīrūnī's 'modernity,'" in Pierre Salmon (ed.), *Mélanges d'islamologie: Volume dédié à la mémoire d'Armand Abel* (Brill, 1974), p. 63.

[8] Qābūs b. Wušmgīr, Ziyarid ruler of Jilan between the tenth and eleventh century also known by his *laqab* Šams al-Maᶜālī (Sun of Eminences), was both a patron of the sciences and an astronomer himself. His interest in astronomical and calendrical matters is well represented by the tower he built in Ǧurǧān, today Gonbad-e Kavūs) as a time-measuring monument. Simone Cristoforetti, "Cycles and circumferences: The tower of Gonbad-e Kāvus as a time-measuring monument," in Stefano Pellò (ed.), *Borders: Itineraries on the edges of Iran* (Venezia: Edizioni Ca' Foscari, 2016), 89-115.

https://doi.org/10.1017/S0957423921000059 Published online by Cambridge University Press

on chronology, discusses the calendars and festivals of several peoples known to the author.[9] In doing so, it touches both calendrical history and the astronomical aspects of time reckoning – al-Bīrūnī discusses, for instance, the calendrical reform of the Khwarazmshāh of mid-tenth century[10] and devotes the last pages of the *Āṯār* to the subject of lunar stations (Ar. *manāzil al-qamar*).[11] The chapter that interests us deals with the calendar of the *Rūmī*, i. e. the Byzantines, listing the days of their calendars. Here, al-Bīrūnī provides the reader with the *anwāʾ* for each day of the year. *Anwāʾ* (singular *nawʾ*) are an astronomical tool for weather prediction that the scientists of the Islamic period most commonly based on a combination of pre-Islamic Arab and Indian astronomical techniques to predict the weather of a given year.[12] As such, *anwāʾ* literature tends to be based on a lunar calendrical system. For the purpose of weather forecasting, though, al-Bīrūnī seems to favor a solar one: the *Rūmī*, i. e. Julian, calendar.

3. CLIMATOLOGY AND WEATHER FORECAST

The passage we intend to discuss here stems from a succinct statement on the *anwāʾ* for the 28th day of Nīsān, or April (¶1).[13] Al-Bīrūnī cites two sources for this day: Eudoxus of Cnidos (ca. 408-355 B. C.) and Abū Saᶜīd Sīnān b. Ṯābit b. Qurra (880-943). The source for the

[9] The calendrical traditions discussed in the *Āṯār* are those of the Persians (Ar. *Maǧūs*), the Soghdians, the Khwarazmians, the *Rūmī* (i. e. the Byzantines), the Jews, the Melikite and Nestorian Christians and, with regards to Lent, Christian sects in general, the Sabians (of Ḥarrān), the pre-Islamic Arabs, and, of course, the Muslims.

[10] On this reform that set the spring equinox as the date of the Iranian New-Year's day, see Simone Cristoforetti, "Nowruz," section III, "In the Iranian calendar," in *Encyclopædia Iranica*, online edition, 2009, www.iranicaonline.org/articles/nowruz-iii.

[11] The relevance of the lunar stations, i. e. the segments of the ecliptic through which the Moon passes in its orbit, serves the astronomical interests of al-Bīrūnī and Ṣulṭān Qābūs the author seems to hold some scepticism over the relation between Lunar stations and meteorological events. Abū Rayḥān Muḥammad Al-Bīrūnī, *Al-āṯār al-bāqiya ᶜan qurūn al-ḫāliya*, ed. Eduard Sachau (Leipzig: Otto Harassowitz, 1923), 338-39.

[12] Daniel Martin Varisco, "The origin of the *anwāʾ* in Arab tradition," *Studia Islamica*, vol. 74 (1991), p. 5-28; Daniel M. Varisco, *Anwāʾ*, in K. Fleet, G. Krämer, D. Matringe, J. Nawas and E. Rowson (ed.), *Encyclopaedia of Islam*, 3rd ed. (Brill, online); Charles Pellat, "Dictons rimés, *anwāʾ* et mansions lunaires chez les Arabes," *Arabica* vol. 2, no. 1 (1955), p. 17-41; Fuat Sezgin, *Geschichte des Arabischen Schrifttums*, vol. 7 (Leiden: Brill, 1979), p. 339-70.

[13] Paragraph numbers refer to our translation, section 10 below.

anwāʾ of Eudoxus may be an Arabic translation of his *Ceimonos Prognostica*, a treatise on bad-weather predictions of Babylonian origin. According to Frisinger, Eudoxus was "the last natural philosopher in the pre-Aristotelian tradition to have taken an interest in meteorology" and, according to Pliny, held "an interesting theory on the periodicity in weather phenomena."[14]

Both Eudoxus and Sīnān are discussed in the opening of the chapter on the *Rūmī* calendar in a brief preamble.[15] Al-Bīrūnī distinguishes between two schools of thought on the *anwāʾ*: those who base their *anwāʾ* on the study of the fixed stars and the relative lunar stations – as we noted above – and those who rely on the days of the solar calendar. Among the latter, al-Bīrūnī counts Sīnān[16] and says that his *anwāʾ* were based on the empirical observations conducted by Sīnān's father, the celebrated Sabean scientist and mathematician Ṯābit b. Qurra (21 CE / 826 AH – 288 CE / 901 AH), over the course of thirty years in Iraq. Al-Bīrūnī points out that the correctness of the *anwāʾ* given by the handful of authorities he refers to in the *Rūmī* calendar chapter are subject to several conditions, such as the character of the year, the region where they were developed, and so on. In other words, al-Bīrūnī conceives these *anwāʾ* more like a climatology based on a heuristic than meteorology:

> The correctness of the *anwāʾ* depends [on certain conditions]. For instance, to foresee the character of the year, the season, the month, whether it will be dry or moist, whether it will answer to the expectations of 40 people or not, to prognosticate it by means of the signs and proofs, of which the astronomical books on meteorology are full. For if the *anwāʾ* agree with those signs and proofs, they are true and will be fulfilled in their entire extent; if

[14] H. Howard Frisinger, *The history of meteorology: To 1800* (Boston: American Meteorological Society, 1983), p. 10, 15; George Sarton, *A history of science: Ancient science through the golden age of Greece* (Harvard University Press, 1960), p. 447.

[15] Al-Bīrūnī, *Āṯār*, 242-43.

[16] Al-Bīrūnī is referring to a treatise on the *anwāʾ* composed by Sīnān for the Abbasid Caliph Al-Muʿtaḍid. This treatise is probably his main source for the weather recording carried out by Ṯābit b. Qurra. It is noteworthy that astronomers coming from a Sabian background such as the Banū Qurra would prefer a solar and rather empiricist approach to weather forecasting, despite their fame for astrolatry. The ample citations provided by al-Bīrūnī are all that remains of Sīnān's treatise on the *anwāʾ*, which seems to have been largely based on the *Phaseis* of Ptolemy. See Julio Samsó and J. Blas Rodríguez, "Las *pháseis* de Ptolomeo y el *Kitāb al-anwā* de Sinān b. Tābit," *Al-Andalus*, vol. 41 (1976), p. 15-48. For a discussion on the impact of Aristotle's *Meteorologica* see Paul Lettinck, *Aristotle's Meteorology and its reception in the Arab world, with an edition and translation of Ibn Suwār's Treatise on meteorological phenomena and of Ibn Bājja's Commentary on the Meteorology* (Leiden: Brill, 1999).

they do not agree, something different will occur.[17]

4. THE RIVER REGIMES

Both of Eudoxus and Sīnān agree that on this day there is a tendency towards rainfall, and that rivers grow in this period. Al-Bīrūnī departs from this statement to elaborate on the physical link between these two phenomena: rainfall and river regimes, and it should be noted that al-Bīrūnī, in agreement with Sīnān, stresses the importance of regional peculiarities when dealing with *anwāʾ*. It is a principle that applies well to the case of rivers regimes and the hydrological record pertaining to the different regimes of the great rivers of the *dār al-Islām* prompts this thematic diversion that moves from hydrology to hydraulics, and closes with a few stray observations on counterintuitive phenomena, that captured al-Bīrūnī's intellectual curiosity.

In the first paragraph (¶1), al-Bīrūnī mentions the rising of both rivers and *awdiya* (pl. of *wādī*, lit. valley). According to his sources, the 28th of April is the day that usually marks the begin of water streams' growth, but he is quick to point out that each river presents its own peculiarities.

In modern hydrology, the term *wadi* is used to indicate typical streams in arid regions which presents occasional waterflows for very short periods of time. Here al-Bīrūnī clearly understands the term more broadly, referring to any stream of moderate proportion that eventually feeds into larger rivers, notwithstanding the arid character of the region where it flows. Therefore, in our translation we have kept with Sachau's rendition of *wādī* as streams.

First, Al-Bīrūnī states that rivers and wadis may present different regimes. Then, he discusses the cases of the four great rivers of the antiquity: Oxus (or Amu Darya), Tigris, Euphrates, and Nile. He notices that the Oxus has a higher flow in summer because of the snowmelt. This is what is nowadays called a nivo-glacial regime, whilst Tigris and Euphrates show an increase in their flow when the season is rainy because precipitation plumpsthe rivers directly flowing in them, or, in today's terms, a pluvial regime (¶2-3).

The term "originary waters" (Ar. *miyāh aṣliyya*, sing. *maʾ aṣlī*) should not be overlooked. Al-Karājī employs the same term, *māʾ aṣlī*, in a very different way. In his *Kitāb inbāṭ al-miyāh al-ḫāfiya* composed in 1019 CE

[17] Al-Bīrūnī, *Āṯār*, 243.

/ 410 AH, he uses the term for the ground water generated in the depth of the Earth from air, adhering to the Aristotelian model of the endogenous cycle.[18] Instead, al-Bīrūnī implicitly disregards the Aristotelian endogenous cycle in favour of an exogenous one.[19] His view on this subject falls squarely in the *paradigme babylonien* of the water cycle that have its oldest extant example in the *Kitāb al-filāḥa al-nabaṭiyya*.[20] This implicit assumption reveals itself again and again in the following pages. In fact, it provides the foundations for al-Bīrūnī's understanding of the natural cycle of water.

Another term that merits a brief discussion is *wuqūᶜ al-andiyya*. Sachau translates it literally as dewfall. Nevertheless, it is apparent to us that al-Bīrūnī is not referring exclusively or even primarily to droplets of water due to condensation. He has in mind the more general phenomenon on precipitation, including rain and snow, as he refers to the latter a few lines later. In this paper, we will always refer to *andāʾ* (pl. *andiyya*) as a general term for natural occurring water from precipitation.

A third element of interest emerging from this paragraph pertains

[18] Mehdi Nadji and Rudolf Voigt, "'Exploration for hidden water' by Mohammad Karaji: The oldest textbook on hydrology?" *Groundwater*, vol. 10, no. 5 (1972), p. 44; Muḥammad al-Karājī, *Inbāṭ al-miyah al-ḫāfiya*, ed. Baghdad ᶜAbd al-Munᶜim (Baghdad; Cairo: Maᶜhad al-Maḫṭūṭāt al-ᶜArabiyya, 1997). On al-Karājī's debt towards the Aristotelian model see Kaveh Niazi, "Karajī's Discourse on hydrology," *Oriens*, vol. 44, no. 1/2 (2016), p. 44-68.

[19] Antiquity knew three main theories on the origin of water springs. Two of them are endogenous, and one exogenous. The oldest, and most correct, one is the exogenous theory exposed by Anaxagoras. According to Anaxagoras, water springs are fed by rainwater that infiltrated the soil. It seems clear to us that al-Bīrūnī is relying on a similar understanding of the water cycle. A second, endogenous, theory is that of Plato. He believed that the water flowing from springs derived from reservoirs on the mountains, either fed by sea water, or generated in the depth of the earth. The third theory, exposed by Seneca and Aristotle, entailed that water was generated inside underground cavities. Aristotle held that this water was generated by condensation of vapor, in analogy to the condensation of water vapor in the sky. Instead, Seneca believed that this generation took place by transmutation of terrestrial and aerial humors. James C. I. Dooge, "Background to modern hydrology," in John C. Rodda and Lucio Ubertini (ed.), *The basis of civilization: Water science?*, proceedings of the UNESCO / IAHS / IWIIA symposium held in Rome, December 2003 (Wallingford: IAHS Press, Centre for Ecology and Hydrology, 2004), p. 3-12; Franco Ravelli, "Il ciclo idrologico naturale nel pensiero dei classici fino agli albori della moderna idrologia," *Rivista di storia dell'agricoltura*, vol. 40, no. 1 (2000), p. 3-32.

[20] El-Faïz, *Les maîtres de l'eau: Histoire de l'hydraulique arabe*, p. 87; Abū Bakr Aḥmad b.ᶜAlī b. Qays al-Kasdānī, *Al-filāḥah al-nabaṭīyah. Al-tarǧama al-manḥūla ilā Ibn Waḥshīya*, ed. Fahd Toufic, 3rd ed. (Damascus: Insititut Français de Damas, 1993-8).

to the geography of the rivers Tigris and Euphrates, on the one side, and the Oxus, on the other. Al-Bīrūnī is confident that the discrepancy between the two fluvial regimes can be explained on a geographical basis, which is of course true since, but not in the terms he puts forward. According to al-Bīrūnī, the reason for this difference between fluvial regimes lies in the fact that the sources of the Oxus are much further north than those of the Mesopotamian rivers. Now, al-Bīrūnī adhered to the school of thought that believed that regions found at the same latitude enjoyed substantially the same climate and opposed the Indo-Persian geographical tradition that divided the world in circular regions called *kishwar* centred around Īrānshahr.[21] In light of this, it is clear why this seemed to him the only reasonable explanation for the phenomenon, leading him to overlook the fact that the sources of the three rivers are approximately at the same latitude. To be fair, his reasoning is not entirely mistaken. The sources of the Oxus are in fact frozen when the Tigris and the Euphrates receive rainfall, but this is due to the fact that the Oxus springs from mountains that are considerably higher and further removed from any nearby sea. It is not clear whether – at least at this point in his life – al-Bīrūnī was mistaken on the geography of the Mesopotamian rivers, on the Oxus, or both.[22]

5. THE NILE'S SOURCES

The argument becomes more complex as the author takes into consideration the case of the Nile (¶4). The fact that the Nile floods in summer would seem to contradict his previous statement on rivers that do not have their sources in the far north. In other words, why do the flows of Tigris and the Euphrates peak during the rainiest season, while the Nile floods during the dry one? To answer this question Al-Bīrūnī puts forward two twin hypotheses, both resting on an increase in precipitation at the whereabouts of the (unknown) Nile's sources.

The first hypothesis is that the sources of the Nile may be water springs located south of the equator, where solar seasons would be reversed. For this reason, argues al-Bīrūnī, the mountain reservoirs feeding those springs would have a rainy cold season in those months when

[21] Zayde Antrim, *Routes and realms: The power of place in the early Islamic world* (Oxford University Press, 2012), 90-91.

[22] A future research may wish to investigate how al-Bīrūnī, whose competence as a geographer would not be under question, understood the hydro-fluvial basins of the known world.

https://doi.org/10.1017/S0957423921000059 Published online by Cambridge University Press

the regions north of the Equator enjoy warm weather. Al-Bīrūnī writes that the sub-equatorial springs of the Nile[23] should receive the most precipitation in winter (Ar. *šitāʾ*). Sachau smoothed the passage translating *šitāʾ* as spring, probably on the ground that al-Bīrūnī mentions these *šitāʾ* precipitations as a possible cause for the growth of the Nile in summer,[24] but a closer translation here would be winter, since it is quite evident that al-Bīrūnī is referring to a sub-equatorial winter, or cold season, that would occur at the same time of summer in the northern hemisphere.

The second hypothesis is that the great Egyptian river gets its water from streamlets located north or at the equator, that may get more water in summer from regional rainfall. Here, even though he does not say it out loud, al-Bīrūnī seems to think of a similar climatic situation as the rainy summers of Yemen he describes in another short digression on regional climatic discrepancies.[25]

6. THE WATER CYCLE AND THE SALINITY OF THE SEA

We find here a further implicit confirmation that al-Bīrūnī saw precipitations as the only source of water for the natural mechanism that feeds rivers. Even more, this assumption holds true no matter the geographical location or seasonal regime of a river. In the case of the Nile, al-Bīrūnī admits that its seasonal behaviour cannot be fully explained, since he lacks empirical data on the sources of Nile,[26] but even this lack of direct observations does not shake his bedrock belief that whatever the environmental conditions may be at the sources of the Nile, we should assume that its water ultimately comes from water precipitation.

In sum, al-Bīrūnī describes three different fluvial regimes relying on an exogenous model of the water cycle. The same understanding of the origin of running waters underlies his discussion of the seasonal regimes of water springs. This part of the digression (¶5) rests on the assump-

[23] See fig. 1.

[24] Abū Rayḥān Muḥammad Al-Bīrūnī, *The chronology of ancient nations: An English version of the Arabic text of the* Athar-ul-bâkiya *of Albîrûnî. or "Vestiges of the past"*, trans. C. Edward Sachau (London: W. H. Allen & Co., 1879), p. 252.

[25] Al-Bīrūnī, *Āṯār*, 245-46.

[26] Here al-Bīrūnī sides with Ibn Sīnā and Ibn Rušd against Aristotle on the habitability of the southern hemisphere. See François de Blois, "Aristotle and Avicenna on the habitability of the southern hemisphere," in Sabine Schmidtke (ed.), *Studying the Near and Middle East at the Institute for Advanced Study, Princeton, 1935-2018* (Piscataway, N. J.: Georgias Press, 2018), p. 188-93.

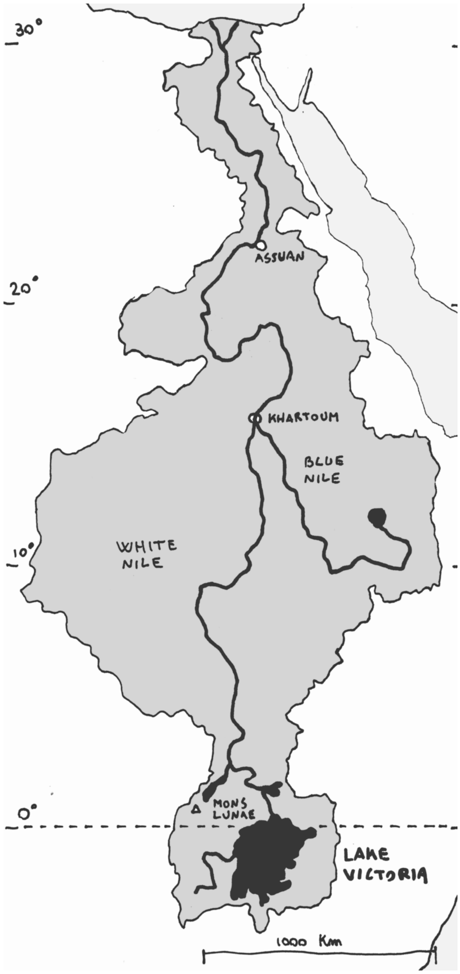

Fig. 1: The Nile and its sources

https://doi.org/10.1017/S0957423921000059 Published online by Cambridge University Press

tion that, in accordance with the divine design, mountain regions are the main recipient of water precipitation. Al-Bīrūnī makes here a quick reference to a book by Ṯābit b. Qurra on the "why the mountains were created" (Ar. *Fī sabab allaḏī lahu ḫuliqat al-ğibāl*) and summarizes his opinion on the matter with a few words. This treatise appears to be lost, but a substantial summary by Miskawayh (d. 1030) is preserved in the *Kitāb al-hawāmil wa al-shawāmil*.[27] Ibn Qurra's argument, such as it is related by al-Bīrūnī,[28] is teleological: the role of mountains as the main recipients of water precipitation is to give salinity to the water that will eventually reach the sea. Miskawayh summary goes further, stating that the presence of mountains, that do not allow the earth to be a perfect sphere, is necessary to have compress and cool down atmospheric vapor, so that it may precipitate as water.

Marwan Rashed discussed the teleological foundation of Ibn Qurra's philosophical thought. Rashed also connected this treatise on the utility of the mountains to Ibn Qurra's treatise on "why sea water is salty" (Ar. *Qawl fī Sabab alladhī Juᶜilat lahu Miyāh al-Biḥar Māliḥa*),[29] where Ibn Qurra states that the reason for the presence of salt is to avoid the corruption that befalls sweet water, for instance in swamps.[30] Al-Bīrūnī addressed the subject a few years later in the *Taḥdīd*, which he wrote in Ghazna between 1018 and 1025 CE:

> The salinity, according to Ṯābit b. Qurra, prevents the water from getting foul, and eliminates putrefaction, which would be disastrous to His intended creatures [...] [God] commanded the winds to drive water vapor, in the form

[27] Abū Ḥayyān al-Tawḥidī and Miskawayh, *Kitāb al-hawāmil wa al-shawāmil*, ed. A. Amīn and S. Saqr (Cairo: 1951), p. 354-6.

[28] The intellectual kinship between al-Bīrūnī and Ibn Qurra is not limited to this subject. For instance, both mathematicians worked on the solar equation, that is the difference between the Sun's mean position on its ecliptic and its actual position. A possible link between al-Bīrūnī and the Ḥarranian scholar could be envisaged in al-Buzjānī, who collaborated from Baghdad with al-Bīrūnī and had been the teacher of al-Bīrūnī's teacher Abū Naṣr Manṣūr b. ᶜAlī b. ᶜIrāq. Michael Fedorov, "The Khwarazmahahs of the Banū ᶜIrāq (fourth / tenth century)," *Iran*, vol. 38, no. 1 (2000), p. 71-75; E. S. Kennedy and Ahmad Muruwwa, "Bīrūnī on the Solar equation," *Journal of Near Eastern studies*, vol. 17, no. 2 (1 April 1958), p. 112-21.

[29] The manuscript, of which an important paragraph was translated by Rashed, is MS Topkapi Saray, Ahmet III 3342, fol. 195v-201v: *Qawl fī sabab alladhī juᶜilat lahu miyāh al-biḥar māliḥa*. Marwan Rashed, "Thābit ibn Qurra, la physique d'Aristote et le meilleur des mondes," in Roshdi Rashed (ed.), *Thābit ibn Qurra: Science and philosophy in ninth-century Baghdad* (De Gruyter, 2009), p. 705-6.

[30] Marwan Rashed, "Thābit ibn Qurra, la physique d'Aristote et le meilleur des mondes," in Roshdi Rashed (ed.), *Thābit ibn Qurra: Science and philosophy in ninth-century Baghdad* (De Gruyter, 2009), p. 706.

> of clouds, to desolate and waterless lands, so that its rain in those lands will refresh and sustain the lives of animals and plants over there, and its rain on the mountains will penetrate and accumulate deep inside them, or will remain on their tops in the form of snow. Further, the accumulated water will form rivers which will carry it back to the sea, but their courses will run by the dwelling places of peoples and animals, who will use the water for drinking and other utilities. These benefits could not have been possible, if the solute in the sea water were other than salt; because vapors of solvents, except the vapors of saline solvent, carry the taste of solutes dissolved in them.[31]

In a following paragraph (¶6) he further clarifies that, since in winter there is a steep increase in water precipitation, some of this water "seeps down into the pores and the mountain caves, and there is stored up" over the course of the cold season. The caves are the reservoirs that feed springs and are not to be confused with the cavities deep in the Earth where water is generated from condensation of the air element in the endogenous model of the water cycle.[32] On the contrary, this statement further confirms that al-Bīrūnī in the *Āṯār* adheres to an exogenous model. Moreover, he employs the model to explain in general terms the functioning of karst system,[33] linking it to the teleological concept of the divine design of the creation, in which the natural world functions as a perfect engine towards its own regeneration.[34] Al-Bīrūnī singles out among water springs those which fall under the category of "bubbling springs," which would seem to negate a physical principle that he seems to hold dear, that water may rise in height only if its reservoir is higher

[31] Abū Rayḥān Muḥammad Al-Bīrūnī, *The determination of the coordinates of positions for the correction of distances between cities*, trans. Jamal Ali (Beirut, 1967), p. 24-25 (repr. Frankfurt: Institute for History of Arabic-Islamic Science, 1992); Abū Rayḥān Muḥammad Al-Bīrūnī, *Taḥdīd nihāyat al-amākin li-taṣḥīḥ masāfāt al-masākin*, ed. Pavel G. Bulgakov and I. Ahmad (Maᶜhad al-Maḫṭūṭāt al-ᶜArabiyya, 1962), p. 34-35 (repr. Frankfurt: Institute for History of Arabic-Islamic Science, 1992). See also a partial translation of this passage in George Kish, *A source book in geography* (Harvard University Press, 1978), p. 216.

[32] This theory is discussed in the Arabic version of Aristotle's Meteorology. Pieter L. Schoonheim (ed.), *Aristotle's Meteorology in the Arabico-Latin tradition: A critical edition of the texts, with introduction and indeces* (Brill, 2000), p. 61-75.

[33] Karst systems are large geological formations due to the dissolution of soluble rocks. They are characterized by underground drainage systems with sinkholes and caves. Karst systems are distributed around the world and characterize vast areas in the Mediterranean region, in north Africa and the vast majority of Iranian Plateau, they are present as well in central Asia.

[34] Seyyed Hossein Nasr, *An introduction to Islamic cosmological doctrines: Conceptions of nature and methods used for its study by the Ikhwān al-Ṣafā, al-Bīrūnī, and Ibn Sīnā* (Bath: Thames & Hudson, 1964), p. 122-25.

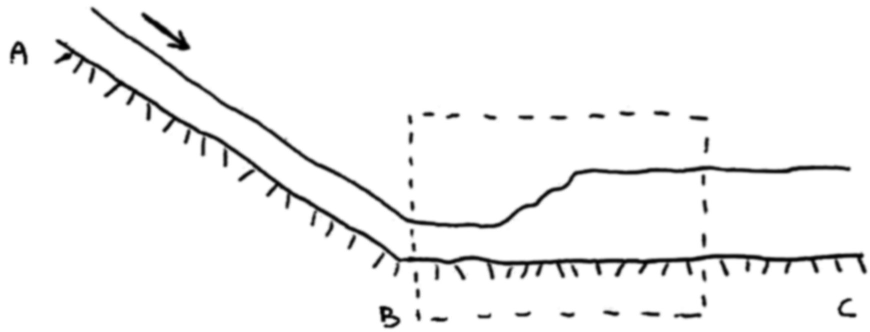

FIG. 2: Hydraulic jump after a slope

than the spring itself. In other words, al-Bīrūnī states that water may not rise higher than its reservoir, that in the case of natural occurring springs is the mountain caves. This general principle appears to have been a point of contention between al-Bīrūnī and some of his acquaintances. The author devotes relatively ample space (¶8-9) to the objection of some anonymous contender who evidently did not accept al-Bīrūnī's thesis that water may never rise above its reservoir.

7. THE HYDRAULIC JUMP

Al-Bīrūnī dismissed the observation as a result of faulty measurements (¶9-10), but we should spend a few words on it. The passage lends itself to a different reading than the one al-Bīrūnī intended. It is evident here that al-Bīrūnī is dismissing an empirical observation because it is not in agreement with his theoretical principle. In agreement with his empirical approach, he cannot argue against it on a theoretical basis and is therefore brought to postulate some form of optical illusion or, worse, incompetence. Nevertheless, the physical phenomenon known today as the hydraulic jump could explain what was reported to al-Bīrūnī. According to his informers, peasants are capable of building irrigation infrastructures that force water to move slightly upwards. The phenomenon occurs in hilly or mountainous countryside – a landscape like the surroundings of Ǧurǧān. There, al-Bīrūnī is told, peasants may deviate steep natural streams into channels with little to none inclination, where the height of the water increases.[35] It may

[35] See fig. 2.

https://doi.org/10.1017/S0957423921000059 Published online by Cambridge University Press

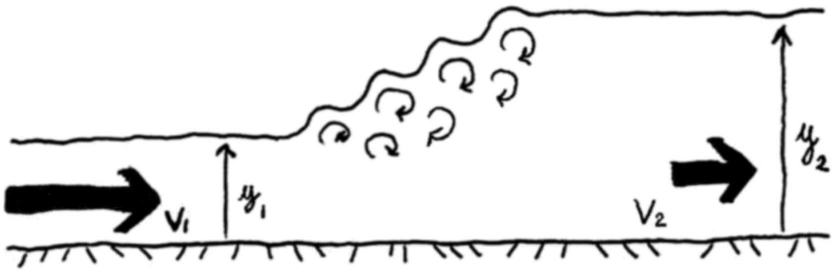

FIG. 3: Hydraulic jump

well be that the anonymous observers were in fact describing what we know today as the hydraulic jump. The hydraulic jump is a phenomenon that occurs when a flow presents a transition from supercritical to subcritical flow. Sparing the physical model and the mathematics connected the phenomenon it is important to notice that a reduced height of the flow corresponds to a higher flow velocity and vice versa such that y1*v1=y2*v2 to ensure the same discharge before and after the hydraulic jump.[36]

8. SYPHONS AND VOID

Be that as it may, al-Bīrūnī builds upon his argument on the physical behaviour of water, taking into consideration the techniques that makes it possible to raise water (¶11). Here, the main concern of the author is to provide an explanation coherent with the principle that water may not rise above its point of origin, countering any possible argument against it in relation to artificial machines. He describes three examples, presented as applications of the syphon: a water-thief or clepsydra (¶12-13), the construction of artificial fountains (¶14), and the natural occurrence of high-pressure springs in Yemen (¶15).

Al-Bīrūnī explains the functioning of the water-thief with the principle of *horror vacui* (¶12-13).[37] The fact that void cannot be or, in alternative, pulls other bodies to fill it, is the reason why water stands in a syphon at a higher level than the water in the basins it connects if the water in the basins is at the same level.[38] The question of whether void is

[36] See fig. 3.
[37] See fig. 4.

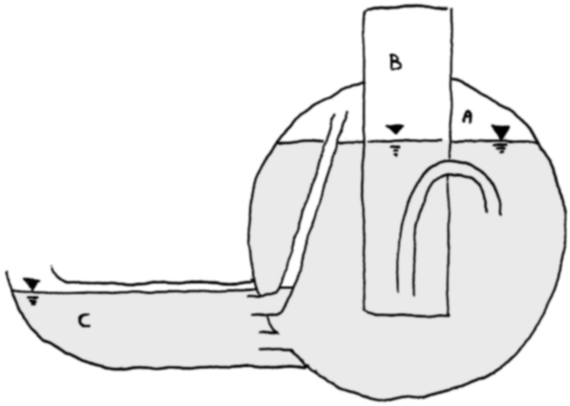

Fig. 4: A self-feeding lamp

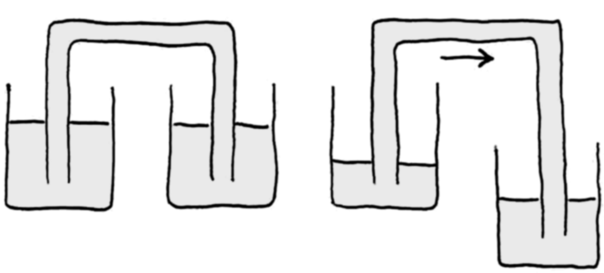

Fig. 5: The syphon

possible or not was much debated at the time. Some, as Ibn Sīnā, and the Muᶜtazilites from Baghdad, opposed the possibility of void. Others, such the Muᶜtazilites from Basra and Abū Bakr al-Rāzī (ca. 250/854-313/925 or 323/935), maintained that void is indeed possible and attracts other bodies. Paul Hullmeine convincingly argued in a recent article that al-Bīrūnī's position on the matter was characterized by a possibilist agnosticism, both in this passage and in later passages, and that he was "at minimum […] not satisfied by the arguments that have been set forth against void's existence."[39]

In the second example (¶14), al-Bīrūnī describes the functioning of artificial fountains built from natural occurring water wells. He differentiates between two kinds of water wells, known today as phreatic and

[38] See fig. 5.

[39] Paul Hullmeine, "Al-Bīrūnī and Avicenna on the existence of void and the plurality of worlds," *Oriens*, vol. 47, no. 1-2 (13 May 2019), p. 3-6, 11.

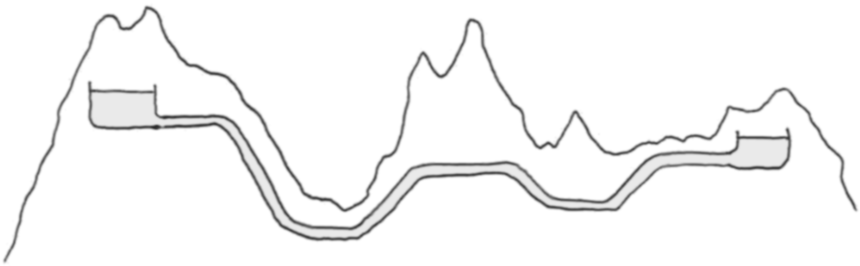

FIG. 6: Hypothetical undergroud syphon

artesian wells. According to al-Bīrūnī, an artificial fountain can gain enough pressure only if its water comes bubbling from the bottom of the well, excluding wells that receive water from surrounding aquifers. This explanation is perfectly coherent with the author's general principle of communicating vessels. Natural wells receiving "bubbling water" or artesian sources are fed by a higher reservoir, which sets the upward limits of the water's rise.

For the third example (¶15), al-Bīrūnī relies on an anonymous oral source on Yemeni water discovery traditional practices. His source states that some water springs may have built up enough pressure to trigger wide scale floods such as the sixth century (ca. 532 CE) *Sayl al-ᶜArīm* that destroyed the Marīb oasis.[40]

After having discussed in depth the general principle, al-Bīrūnī mentions a few *ᶜağāᵓib*, natural or man-made counterintuitive phenomena (¶16-24). For some of them, he provides sources and some explanation, for others, we are left in the dark.

The first case cited by al-Bīrūnī is the lake of Sabzarūd (¶16-18), which is also the most relevant one to understand al-Bīrūnī's view of hydraulics at this early stage in his career. Sabzarūd lake is a small pond of water known today as *Chashmeh Su*. The fact that the old and new names describe its green colour, "green lake" and "green light" respectively, seems to confirm that. Al-Bīrūnī does not say why he chose this lake as an example, but it has probably to do with the fame of Sabzarūd

[40] *Sayl al-ᶜArīm*, literally "the flood of *ᶜArīm*," probably from Sabian *ᶜrm* meaning dam. The expressions *al-sayl al-ᶜarīm* and *sayl ᶜarīm* came to mean any highly violent flood. W. W. Müller, *Mārib*, EI2; Ingrid Hehmeyer, *A history of water engineering and management in Yemen: Material remains and textual foundations* (Brill, 2019), p. 23-24, 48-56.

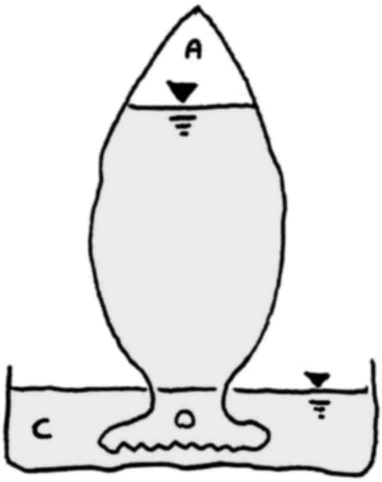

Fig. 7: *Al-dahǧ*

since Pre-Islamic times. Fatemeh Jahanpur has argued that there was a temple by its shores.[41] According to a report by Ibn Balḫī, a white horse emerged from its green waters to trample the unjust ruler Yazdagird I.[42] The lake was therefore well known, which should explain al-Bīrūnī's interest in this pond.

The actual origin of Sabzarūd's waters may simply be seasonal snowfall, but al-Bīrūnī never considers this possibility.[43] Instead, he seems certain that it must be fed by some distant reservoir, located on a higher mountain. All three explanations provided by the author rely on the same principle of the communicating vessels.[44] In one case the reservoir is higher than the green lake (¶16), in another it is on the same level (¶16), and in the third a more complex natural mechanics is at work (¶18). Al-Bīrūnī compares it to a machine or instrument called *al-dahǧ*,

[41] Fatemeh Jahanpur, "Taᵓammoli Dar Nām-e Chashmeh Su," *Faslnāmeh Tārikh-e Iran Bāstān*, vol. 3 (1385/2006), p. 1-16, esp. p. 12. On this lake and its legends see also Davoud Monchi-Zadeh, *Topographisch-historische Studien zum Iranischen Nationalepos*, vol. 2 (Wiesbaden: Deustche Morgenländische Gesellschaft, 1975), p. 201-203.

[42] Parvaneh Pourshariati, *Decline and fall of the Sasanian Empire: The Sasanian-Parthian confederacy and the Arab conquest of Iran* (London: I. B. Tauris, 2008), p. 66-67.

[43] This is curious, since snowmelt was one the sources of water for small lakes on mountaintops theorized by al-Karaǧī, and it may suggest that al-Bīrūnī was not aware of his work at time. Niazi, "Karajī's discourse on hydrology," p. 64.

[44] See fig. 6.

of which we have found no other mentions. Fortunately for us, al-Bīrūnī explains with some detail its functioning[45] and says it is quite like the self-feeding lamp, of which we have descriptions in other technical works, such as the *Book of ingenious devices* by Mūsā b. Šākir.[46]

It is not clear how this model would translate into the physical reality of a mountain lake, but our best guess is that al-Bīrūnī envisions here a wider closed reservoir in the peaks around the Sabzarūd, which lies in a small valley closed on all sides by mountain peaks. These reservoirs would be connected to the lake by both a submerged water spring and an opening at water level, which would act as a regulation system, allowing the inflow of water as the lake naturally dries up, and preventing it to flow when the level of the lake surpasses its closing the only source of air to the reservoir.

Al-Bīrūnī mentions two more lakes that, to his knowledge and probably from his reading of geographical literature, lie on top of their respective mountain without any evident reservoir higher than themselves. The first one is a very small lake near a mountain called Mankūr, in the country of the Kimek (Ar. *Kīmāk*) (¶19). The Kimek lead a Turkish confederation located between the rivers Ob and Irtysh rivers, and the identification of said mountain is debated. Marquart proposed in the thirties a restoration of Mankūr in *min kol*, meaning "thousand lakes,"[47] while Minorsky advocated an identification with a mountain mentioned in the *Ḥudūd al-ᶜalam*[48] as K.NDĀV.R-BĀGHĪ or *kandūr*, "which would look very much like *mankūr*."[49]

The last case brought up by al-Bīrūnī, a small lake on the mountains of Bāmiyān, could not be identified. From this point onwards, the author leaves aside any scientific inquiry and the digression becomes a mere presentation of marvellous and strange phenomena. In some cases, not even related to water, as is the case of the last anecdote retold by al-Bīrūnī on the self-moving column in Alexandria. The purpose of these

[45] See fig. 7.

[46] Donald R. Hill, *The book of ingenious devices by the Banū (sons of) Mūsa bin Shākir* (Dordrecht: D. Reidel Publishing Company, 1979), p. 232.

[47] J. Marquart and W. Bang, "Über das Volkstum der Komanen," *Osttürkische Dialektstudien*, vol. 13, no. 1 (1914), p. 25-238.

[48] Anonymous, *Hudud al-ᶜalam "The regions of the world:" A Persian geography, 372 AH – 982 AD*, trans. Vladimir Minorsky and Vasilij Vladimirovič Bartol d (London: Messrs Luzac & Co., 1937), p. 66.

[49] Minorsky and Bartol d, 202; V. Minorsky, "The Khazars and the Turks in the Ākām Al-Marjān," *Bulletin of the School of Oriental Studies, University of London*, vol. 9, no. 1 (1937), p. 141-50.

factoids is probably to give the reader a chance to rest from the more technical discussion of the digression, before returning to the structure of the *Rūmī* calendar, which is the main subject of the chapter.

9. CONCLUSIONS

In conclusion, the main preoccupation of al-Bīrūnī in the brief digression translated and analysed in the present paper was to elaborate on the general principle that water may not rise above its point of origin. For us, this passage is first and foremost a significant example of how al-Bīrūnī conceived the water cycle, at least at the time of his employment at the Ziayrid court. While it is true that al-Bīrūnī does not state openly in these pages a belief in the exogenous cycle, it is abundantly clear that he thought of the natural water cycle as a closed system for both scientific and teleological reasons. Al-Bīrūnī presents the reader with a counterargument to his central statement that he proceeds to refute. The case of the uprising channel is not discussed at length, but it is nonetheless noteworthy. Based on al-Bīrūnī's description of the phenomenon, it could be hypothesized that his anonymous source, or contender, witnessed a hydraulic jump being exploited for irrigation purposes.

10. TRANSLATION

[1] On the 28th [of Nīsān] there is wind according to the Copts, and rain according to Eudoxus. Sinan confirms the rain from his own observations. It is said that the south wind blows on this day, and that the streams and rivers begin to grow. This increase of the water does not happen in all streams and rivers in the same way. On the contrary, they differ a great deal from each other in this respect.

[2] For instance, the Oxus has high water when there is little water in the Tigris, Euphrates, and other rivers. This happens because [rivers] that originate from streams in colder places have more water in summer and less in winter. The reason for this is that the greatest part of their originary waters is gathered from springs. Now, their growth or shrinking depends on the amount of precipitation in those mountains from which the rivers come or through which they pass, so that their flows pour into the rivers.

[3] It is no secret that there is more precipitation in winter and beginning of spring than in any other season, and that it freezes during

https://doi.org/10.1017/S0957423921000059 Published online by Cambridge University Press

those seasons in the northernmost countries, where the cold is intense. [Therefore,] it is when the air gets warm and the snow melts, that the Oxus rises. As for the water of the Tigris and Euphrates, their sources are less high up in the north. Therefore, the growth of these two happens in winter and spring, because the precipitation flows into the rivers just as soon as it falls. Moreover, the portion that may have been frozen melts away in the beginning of spring.

[4] As for the Nile, it grows when Tigris and Euphrates shrink. This is because its source lies in the Mons Lunae, as it has been said, beyond Assuan – the city the Abyssians in the southern region – either at the Equator, or beyond it. This is, however, a matter of doubt, because those surroundings are not inhabited, as we said earlier. It is evident that in those regions any freezing of moist substances is impossible. Therefore, it could either be that the growth of the Nile is caused by precipitated water, as it is evident that the water does not stay where it has fallen, but flows off to the Nile at once, or that it is caused by the springs, that have the most water in winter. [In the latter case,] the Nile rises in summer, because when the sun is near us and at our zenith, it is far away from the zenith of those regions whence the Nile originates, and it is winter there.

[5] Regarding the question why the water of springs is most copious in winter, it is because the all-wise and all-mighty Creator intended to place the mountains [on earth] for a number of beneficial uses, some of them mentioned by Ṯābit b. Qurra in his book on why the mountains were created. This reason [that interests as here] is to fulfil [his] intention of making the water of the seas salty.

[6] Clearly, precipitation in winter is higher than in summer, and they are higher in the mountains than in the plains. When [this water] falls, a part of it flows away in the torrents and the remaining part seeps down into the pores in the mountain caves, and there it is stored up. Afterwards, it begins to come out from the holes that are called springs. That is the reason why [this water] is most copious in winter: it is because there is more of its own substance. Moreover, if these mountain caves are clean and pure, the water flows out just as it is, agreeable [to the taste]. If that is not the case, the water acquires different qualities and peculiarities, the causes of which are hidden from us.

[7] With regards to the bubbling of the springs and the upward rising of the water, they are due to the fact that their reservoirs lie higher than [the springs] themselves, as is the case with artificial well-springs, for water may rise in height for this reason only.

[8] Many who just say "God knows best" when confronted with what they ignore of natural sciences have argued with me on this subject. In support of their conviction, they relate that they have observed the water rise in rivers and watercourses, and that the water was rising as it flowed away. They assert this only because of their ignorance of the physical causes and their inaccuracy in distinguishing between what is higher and what is lower.

[9] The fact is that they observed running water in the middle of mountain streams, which go downward at the rate of 50-100 cubits and more per one earth mile of distance.[50] If, somewhere along its course, the peasants dig a small channel, and this channel is built with just a gentle inclination, the water [at first] flows just a little, until it rises to a height that exceeds that of the water of the stream [from which it departed].

[10] If someone who has no training believes that course of the wadi is horizontal or with a small inclination, he will imagine that it is necessary that the small channel is rising in height, and it is impossible to free their mind from this illusion unless they acquire experience with the instruments by which the land is measured, and by which rivers are dug and excavated. When they measure the land where the water is flowing, something different from what they believed becomes clear to them. In alternative, they need to study physical sciences and know that the motion of water proceeds towards the centre [of the earth,] and to any point that is nearest to it.

[11] Of course, water may rise as much as it is wanted to, even to the tops of the mountains, when its point of [final] descent is lower than its point of [initial] ascent and anything that might occupy its place when the water vacates it is prevented from doing so. [Since] the water flows naturally only thanks to the co-operation of [something] that forces it, which [in the present case] is the air. This has been done often in rivers on whose path there were mountains which were impossible to cut.

[12] An illustration of this principle is the instrument called Water-thief. If you fill it with water and put both its ends into two vessels, in both of which the water reaches to the same level, then the water in the Water-thief stands still even for a long time, not flowing off into either of the two vessels, because both vessels are equally close [to the center of the earth,] and it would be impossible for the water to flow off equally into both vessels, for in that case the instrument would void itself and the void is either a non-ens, as some philosophers suppose, or it is an

[50] One *mīl* equals 4 000 *ḏirāᶜ*. Walter Hinz, *Farsaḵẖ*, in EI2.

ens which attracts bodies, as others believe. If the existence of [the void] is impossible, it will not be there, and if it is something which attracts bodies, it will hold water back, not letting it flow off, except in case its place is occupied by some other body.

[13] But if one end of the Water-Thief is moved a little lower (than the other), then what is inside the [higher] vessel flows off towards it. This happens because, since it has been lowered, it has come nearer to the centre of the earth, and so [the water] flows towards it, and the flux becomes continuous in consequence of the adhesion and connection of the atoms of water amongst each other. [The flow] continues until the water of that [higher] vessel, whence the water is drawn, is finished, or until the level of the water in the [lower] vessel where it flows is equal to the level of the water in the [higher] vessel whence it is drawn, when the question is in original state once again. On the mountains, [people] have proceeded in a similar way.

[14] It is quite true that the water rises in artificial fountains out of wells, in case they have bubbling water. [On the contrary,] there is a sort of well-water, which is gathered from droppings from the sides, that does not rise at all. [This latter kind] is acquired from waters that are nearby, and the level of the water which is gathered in this way is parallel to the level of those waters by which it is fed. But there is one kind of water which bubbles at the bottom of the well. It is desirable and possible that this water people springs from beneath the earth, flowing on over above ground. This latter kind of water is mostly found in countries near to mountains with no lakes or deep rivers. If the source of such water is a reservoir above the level of the earth, the water rises bursting, if it is confined (through a small pipe). but if its reservoir is lower, the water does not reach the level of the earth and it does not burst out. Frequently the reservoir is higher by thousands of cubits in the mountains; in that case the water may rise up, for instance, to the fortresses or to the tops of the minarets.

[15] I heard that people in Yemen at times dig until they come to a rock under which they know that there is water. Then they knock upon this rock, and by its sound they ascertain the quantity of the water. Then they bore a small hole and examine it, if it is safe, they let the water bubble out and flow where it likes. But if they have some fear about the hole, they hasten to stop it up with gypsum and quicklime and to close it over repeatedly. They do so because sometimes they fear that from such a hole a spring like the Flood of ʿArim might originate.

[16] As to the water on the top of the mountain between Abarshahr

https://doi.org/10.1017/S0957423921000059 Published online by Cambridge University Press

and Ṭūs – a small lake of one farsang in circumference, called Sabzarūd – there is no doubt that its case is as follows: Either it comes from a reservoir higher than the lake itself, although it may be far distant. The water flows into it in such a quantity as corresponds to that which the sun dries up and evaporates. At which point, the water of the lake stands still in the same state.

[17] Or its material is derived from a reservoir which lies on the same level with the lake, and therefore the water of the lake does not rise above that of the reservoir.

[18] Or the deal with its sources is like that of the water of the instrument called al-Dahj, and the self-feeding lamp. The [general] idea is this: You take a jar for water, or an oil-vase; in several places of the edge of the vase [or of the jar] you make fine splits, and you make a narrow hole lower than the mouth by so much as you wish the water to remain in the basin [where you will place the jar] or the oil in the lamp [where you intend to place the oil-vase]. Then, you fill [the jar or the oil vase] up and you turn the jar upside down in the basin or the oil-vase in the lamp. Then the water or the oil will flow out through the fine splits, until they reach the level of the [narrow] hole. When [the oil or water] just under the level the hole is consumed [so that the level of the fluid decreases under the hole], then, [the oil or water] which lies in the proximity of the hole flows off [to the lamp or the basin, through the fine splits]. In this way both oil and water keep the same level.

[19] Similar to this little lake, there is a sweet water spring in the country of the Kīmāk on a mountain called Mankūr, as large as a great shield. The surface of its water is at the same level of its margins. Sometimes, an army drinks out of this spring, and still it does not decrease by a finger. Near this spring there is a rock with the traces of the foot, two hands with the fingers, and two knees of a man who had been worshipping there; also, the traces of the foot of a child, and of the hoofs of an ass. The Ghuzz Turks worship them when they see them.

[20] There is another small lake, similar to those, in the mountains of Bāmiyān, one-mile square, on the mountain top. The water of the village which lies on the slope of the mountain comes down through a small hole, enough for their needs, but they are not able to make it larger.

[21] Sometimes, the bubbling occurs also in a plain country which gets [its water] from a high reservoir. The bubbling gets high if there is nothing that prevents it, and when any obstacle is removed, as has been the case in the village between Bukhara and al-Qāriya al-Ḥadītha, mentioned by al-Jayhānī, where there is a hill where people who were

https://doi.org/10.1017/S0957423921000059 Published online by Cambridge University Press

searching for hoard and hidden treasures went digging. At some point they found water, and were unable to contain it, so that it has been flowing ever since till this day.

[22] If you are impressed [by these phenomena], you will be as well for the place called Fīlawān, in the neighborhood of al-Mihrağān. This place is like a ledge dug out in the mountain, from the roof of which water is always percolating. When the air gets cold, the water freezes over it in long icicles. I have heard the people of al-Mihrağān claim that they hit the place with pickaxes, and that the spot which they hit became dry, while the [output of] water never increased, even though one would rationally think that it should at least remain the same, if it does not increase.

[23] What al-Jayhānī relates in his *Kitāb al-mamālik wa al-masālik* of the two columns in the grand mosque of Qayrawān, made of an unknown material, is even more wonderful. People claim that they sweat water on every Friday before sunrise. What is marvelous about it is this takes place only on Friday. If they said it may freely occur on any of the week, it could depend from the moon's reaching a certain place of the sun's orbit, or some similar reason. This, however, is not the case, since it must be Friday [for this phenomenon to occur.] They say that the Byzantine king offered to buy them. He said: "The Muslims would benefit more from their payment than from two stones in the mosque." But the people of Qayrawān refused the offer, saying: "We shall not bring them out from the house of God into that of the devil."

[24] The self-moving column which is in Alexandria is even more impressing than this: It inclines towards one of its sides. People put something underneath when it inclines, and when it gets upright again it cannot be taken away. When glass is put underneath, the sound of its breaking and crushing can be heard. This is no doubt that something has been manufactured, as also the place [where the column stands] points to that. Now we return to our original subject."