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Paisajes, escrituras, símbolos y arquitecturas del antiguo Irán
Landscapes, Scriptures, Symbols and Architectures of Ancient Iran

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Introducción

El antiguo Irán, Persia, pero también Elam, constituye un ámbito de estudio apasionante del que cada vez tenemos más información. El número vigésimo sexto de nuestra revista hace un repaso por distintos aspectos que son objeto de investigación en la actualidad, y lo hace de la mano de investigadores iraníes, franceses, italianos y españoles.

Solemos recordar que la inscripción de Darío en Behistun fue la llave a partir de la cual se pudo descifrar el cuneiforme. La inscripción estaba escrita en persa antiguo, en babilonio y en elamita. A partir del persa se pudo comenzar a descifrar el babilonio, y el elamita tardaría algo más. Es muy interesante que la inscripción estuviese escrita en la lengua originaria de la zona, y que los aqueménidas lo reconociesen con su inscripción como tal. Visiones exógenas y posteriores no siempre han querido ver esta vinculación.

El trabajo de Silva Balatti sobre materiales inscritos del Irán aqueménida continúa una línea de trabajos sobre la escritura irania que aún hoy nos da alegrías y resultados interesantísimos.

La arquitectura irania es objeto de varios artículos en este volumen. El de Davide Solaris y Roberto Dan sobre el significado y la arqueología de Masjed-e Soleyman, reinterpretando su origen y su contexto socio-cultural, es el primero de ellos. El trasvase cultural que estudia Pierfrancesco Callieri de parte de babilonios en Persépolis nos habla de arquitectura, pero también de arqueología y de la información que obtenemos de ellas.

Carlos Fernández Rodríguez aborda la gestión del agua y de su papel en la habitabilidad en el sur de Irán durante la Edad del Hierro, que debe relacionarse con lo que sucede al otro lado del Golfo. Fernando Escribano Martín indaga en lo que conocemos como "jardín persa", en sus orígenes y en cómo ha evolucionado, y para eso debe partir de Pasargada en Persia, pero ir también más atrás para comprenderlo.

Sébastien Gondet aborda el desarrollo de la agricultura y la historia de la ocupación de la Persépolis aqueménida, aspecto clave para entender el funcionamiento de la capital persa, y Alireza Khounani los viñedos de la Nisa arsácida parta, un ejemplo concreto de agricultura y de comercio en otro periodo clave de la historia irania.

El ámbito material viene tratado con el trabajo de Giulio Maresca sobre la cerámica de Sistán en la Edad del Hierro, o el estudio más específico de Negin Meri sobre una bulla concreta conservada en una institución museística de Teherán.

Cerramos esta temática tan variada e interesante que hemos ido tratando de agrupar en esta introducción con el trabajo de Zahara Gharenhkhani, en el que realiza unas reflexiones sobre criaturas híbridas de la Persia preislámica y recapacita sobre su simbolismo, que va mucho más allá del tiempo en el que fueron concebidas.

La panoplia de estudios de diverso orden que aquí presentamos da cuenta del rico mundo que se está investigando en torno al Irán antiguo, cuyas manifestaciones elamita y persa, cada vez más claramente vinculadas, trascendieron también en el tiempo y en el espacio.

F. Escribano Martín, C. del Cerro Linares, C. Fernández Rodríguez y F. L. Borrego Gallardo

Foreword

Ancient Iran, Persia, and Elam constitute a fascinating field of study about which we have more and more information. The 26th issue of our journal allows a revision through several aspects of the current research along with Iranian, French, Italian and Spanish scholars.

We usually remember that cuneiform was deciphered thanks to the Darius' inscription in Behistun. It was written in Old Persian, Babylonian and Elamite. From Persian, it was possible to start deciphering the Babylonian, even if the Elamite took more time. It is indeed very interesting that the inscription was written in the native language of the region, and that Achaemenids recognised it. Some outside and later views have not understood this correlation.

The study of Silvia Balatti about written materials of Achaemenid Iran continues a line of research about the Iranian writing system that even today provides very interesting results.

The Iranian Architecture is the aim of some papers in this issue. The first one is the contribution of Davide Solaris and Roberto Dan about the signification and the archaeology of Masjed-e Soleyman, reinterpreting its origin and socio-cultural context. In the same way, the cultural transfer on behalf of Babylonians in Persepolis analysed by Pierfrancesco Callieri is related to architecture but also to Archaeology and to the information that we obtain from them.

Carlos Fernández Rodríguez explores water management and its function in the habitability of Southern Iran during the Iron Age, showing that it is to the situation on the other side of the Gulf. Fernando Escribano Martín investigates what we know as the 'Persian garden', as well as its origins and development. To do this, he should start from Pasargadae in Persia, but also from more ancient times.

Sébastien Gondet analyses agriculture's development and history of the Achaemenid Persepolis' occupation, which is a key aspect for understanding the functioning of this Persian capital. On the other hand, Alireza Khounani presents the vineyards of the Arsacid-Partian Nisa, a concrete example of agriculture and trade in another important period of Iranian history.

In terms of material culture, Giulio Maresca presented a paper about the Sistan pottery in the Iron Age, and Negin Meri developed specific research of an example of a bulla kept in a Museum of Teheran.

We close this wide ranging and interesting theme that we group in this foreword with the studies of Zahara Gharenhkhani reflects on some hybrid creatures of the Pre-Islamic Persia, reconsidering their symbolism, which goes beyond the time when they were conceived.

The array of studies of different kind that we present in this issue accounts for the rich world that is under investigation around Ancient Iran, whose Elamite and Persian manifestations, progressively more related, transcend both in time and space.

F. Escribano Martín, C. del Cerro Linares, C. Fernández Rodríguez and F. L. Borrego Gallardo

OBSERVATIONS ON THE ENVIRONMENTAL SETTING OF THE AGRICULTURAL DEVELOPMENT AND OCCUPATIONAL HISTORY OF ACHAEMENID PERSEPOLIS

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ABSTRACT

This article deals with the environmental setting of Persepolis during the Achaemenid period (6th – 4th cent. BC). In addition to its symbolic and administrative functions as a central place, Persepolis was the result of a large-scale development project over at least a dozen square kilometres implemented in successive stages, which left large spaces for farming activities attested in the Fortification Archives. Following a review of the regional geographical setting, data focusing on the properties of soils and hydrography provide a more precise picture of the natural landscape of Persepolis. The hydraulic installations, known thanks to archaeological fieldwork, appear to be adapted to the properties of soils and suitable for developing intensive farming. Studies of hydrographic conditions show that the Pulvar river channel running through the region would have been less incised into its floodplain than in modern times, with consequences for the availability of water at Persepolis and its occupational history.

KEYWORDS

Iran, Fars, Persepolis, Pulvar, palaeoenvironment, soils properties, hydrography, land-use, hydraulic facilities, farming.

RESUMEN

Este artículo trata del entorno medioambiental de Persépolis durante el periodo aqueménida (ss. VI-IV a.C.). Además de sus funciones simbólicas y administrativas como lugar central central, Persépolis fue el resultado de un proyecto de desarrollo a gran escala que abarcó al menos una docena de kilómetros cuadrados y se llevó a cabo en etapas sucesivas, que dejó amplios espacios para las actividades agrícolas, como atestiguan los Archivos de la Fortificación. Tras una revisión del entorno geográfico regional, los datos centrados en las propiedades de los suelos y la hidrografía proporcionan una imagen más precisa del paisaje natural de Persépolis. Las instalaciones hidráulicas, conocidas gracias a los trabajos arqueológicos parecen estar adaptadas a las propiedades de los suelos y adecuadas para el desarrollo de la agricultura intensiva. Los estudios de las condiciones hidrográficas muestran que el cauce del río Pulvar, que atraviesa la region, habría estado menos encajado en la llanura aluvial que en época moderna, con consecuencias para la disponibilidad de agua en Persépolis y en la historia de su ocupación.

PALABRAS CLAVE

Irán, Fars, Persépolis, Pulvar, paleoambiente, propiedades del suelo, hidrografía, uso del suelo, instalaciones hidráulicas, agricultura.

1. Persepolis, a central place and a landscaping project

Discussions of the role of Persepolis have for a long time focused on the monumental terrace founded under the rule of the Great Achaemenid King Darius I in the early part of his reign (520-486 BC). The construction of the Persepolis Terrace in the homeland of the

Persians, and of the 50ha Royal Area surrounding it[1], was a huge and long-term building project which bore manifold symbolic and political meanings[2]. The architectural program of the terrace and its surroundings served at first to symbolize Achaemenid power over imperial space. The discovery of thousands of inscribed clay tablets at the beginning of the 1930s on the terrace, and their still ongoing translation and analysis, have also shed light on the role of Persepolis as an administrative centre[3]. Dated back to the reign of Darius, the Persepolis Fortification Archive record activities of officials in charge of land management within a region corresponding mainly to the present extent of Fars province. Persepolis, or Parsa as it is named in the archives, was a central place and the region's capital "city"[4]. On a more local scale, the archives show that the land surrounding the terrace was cultivated and permanently populated by a variety of inhabitants (members of the aristocracy, agents of the administration, soldiers, craftsmen, farmers, semi-dependant workers…).

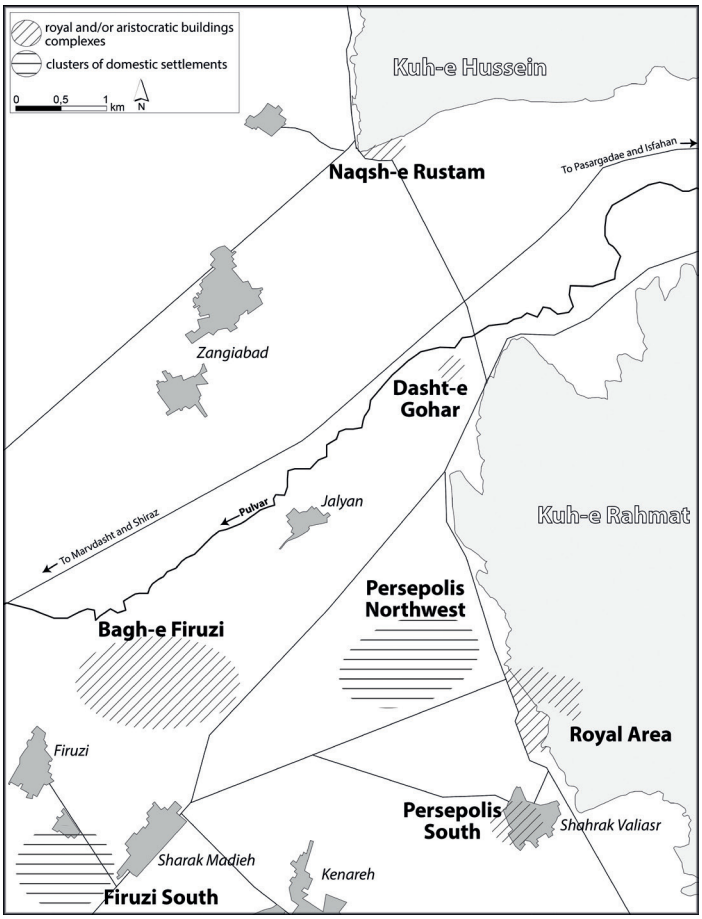

Fig. 1. Simplified map of the Persepolis Settled Zone, showing the distribution of clusters of Achaemenid settlements (adapted from Gondet 2018: 198-Fig. 4, with modifications; CAD S. Gondet).

[1] Mousavi 2012: 10-50 provides a detailed presentation of the results of the successive archaeological campaigns undertaken on the terrace and in its surroundings as from the 1930s.

[2] Among an extensive list of references on this topic, see the following publications: Briant 1996: 99, 183-184; Kuhrt 2007: 469-471: Mousavi 2012: 51-56; Root 2015: 3-11; Canepa 2018: 32-35; Boucharlat 2020; Matthews, Fazeli Nashli 2022: 483-487.

[3] See Henkelman 2017 for a detailed analysis of the Persepolitan institutional landscape reconstructed thanks to the archives; see Henkelman, Kaniuth, Mohammadkhani 2023: 228-229 for a concise overview of the archives' content and of the bibliography related to their current study.

[4] The term "city" linked to "capital" or "centre" is used to characterize Persepolis by Kuhrt 2007: 470; Mousavi 2012: 55-56; Root 2015: 13. See discussions on the use of these terms in *ibid.*: 11-14; Gondet 2018: 186-189; Askari Chaverdi, Callieri 2020: 178; Boucharlat 2020: 59; Callieri 2022.

Given the intricate nature of Persepolis, archaeologists have long tried to reconstruct the physical reality of Achaemenid occupation at Persepolis beyond the Royal Area[5]. The spatial organization of Persepolis needs to be approached at a scale of several square kilometres encompassing the known complexes of Achaemenid monuments or the clusters of settlements known around the terrace[6]. The area, which we have suggested calling the Persepolis Settled Zone[7], is bounded to the south by the Royal Area, by the royal necropolis of Naqsh-e Rustam 6km to the north, and by the modern village of Firuzi 5km to the west (Fig. 1). During the last twenty years, a succession of archaeological projects, implemented in the frame of programs led by the Parsa Research and Conservation Centre, have focused their efforts on the exploration of fields west of the terrace. Despite the destruction of archaeological sites caused by agricultural encroachment, a combination of large-scale mapping works —based on pedestrian surveys and remote sensing techniques (geophysics)— with targeted excavations has revealed parts of the preserved traces of the Achaemenid layout[8]. Fieldwork focused mainly on the Persepolis Northwest and Bagh-e Firuzi areas. In the Persepolis Northwest, the surveys and excavations revealed a mosaic of built-up spaces and others left unbuilt, distributed within a rectangular grid system of ditches mapped over more than 120ha (Fig. 2). In the Bagh-e Firuzi, at least eleven Achaemenid sites —nine displaying remains of monumental architectural features— are distributed across a surface of at least 150ha, spaces between them appearing as unbuilt and cut through by ditches. It appears that Persepolis is the result of a large-scale and certainly long-term development project following a peculiar layout that can be characterized as diffused[9]. Spaces around the Royal Area presented an open landscape characterized by multi-centred clusters with low density of buildings, the setting for daily-life activities of the permanently settled population, and by the prevalence of green areas[10]. The settled areas were criss-crossed by drainage facilities, dating back to the Achaemenid period[11], demonstrating that they were carefully landscaped over dozens of hectares.

The morphology of Persepolis raises manifold challenges and questions. One can hardly define and analyse occupation around Persepolis by following the standard approaches of studies in urbanism. The archaeological data revealed that the Persepolis micro-region was subjected to a large-scale landscape development project rather than the construction of a densely built-up city within well-defined boundaries. Consequently,

[5] In an article presenting his excavation program at Persepolis, Herzfeld 1929 provides an early attempt to describe the remains of the city around the terrace. Sixty years later, Sumner 1986 published a review of the archaeological data on the Achaemenid settlement in the plain and on the "city or town" (*ibid.*: 9) around the terrace.

[6] See the comments of Boucharlat 2003: 264-265 published before the recent resumption of archaeological work at Persepolis and based on a revaluation of the data published by Sumner 1986. See also Kuhrt 2007: 470 connecting Naqsh-e Rustam to the city.

[7] Boucharlat, De Schacht, Gondet 2012; Gondet 2018; Boucharlat 2020; Askari Chaverdi, Callieri 2020; Matthews, Fazeli Nashli 2022: 480. Alternatively, the area is called "Territory of Parsa" in Talebian 2008: 182-Fig. 10; "Greater Persepolis" in Root 2015: 12-13; "Persepolis region" in Henkelman, Stolper 2021: 173 and in Henkelman 2021: 142.

[8] Talebian 2008; Boucharlat, De Schacht, Gondet 2012; Askari Chaverdi, Callieri 2012; Askari Chaverdi, Callieri, Matin 2014; 2017; Askari Chaverdi, Callieri (eds.) 2017; Gondet, Mohammadkhani, Askari Chaverdi 2018. See review of the results in Gondet 2018: 197-201; Boucharlat 2020: 59-65; Askari Chaverdi, Callieri 2020; Callieri 2022; Matthews, Fazeli Nashli 2022: 480-483.

[9] Root 2005: 13; Canepa: 2018: 25-26; Gondet 2018: 205; Askari Chaverdi, Callieri 2020: 185; Callieri 2022: 133.

[10] Boucharlat 2020 attempts to provide a comprehensive reconstruction of the landscape of Persepolis as it appeared to the eyes of visitors.

[11] Askari Chaverdi, Callieri 2012: 236-237, 2020: 183; Callieri 2022: 128.

Persepolis must also be studied by considering its natural landscape, how the latter was managed and transformed. Recent results coming from textual, palaeoenvironmental, and archaeological sources provide insights on two topics that the present article examines in that perspective. The first is the nature of unbuilt spaces, so far vaguely described as green areas, while recent publications have demonstrated intensive agrarian activities —especially tree cultivation— in the Persepolis area. The second topic concerns the chronology of the development of Persepolis, on which archaeological work in the Bagh-e Firuzi area provides new hypotheses. After a presentation of these results and their outcomes, the article deals with the general environmental setting and focuses on the questions of soil fertility and hydrographic conditions during the Achaemenid period. In some respects, the cross-analysis of various data on these two factors could enlighten aspects of agrarian development at Persepolis and its occupational history.

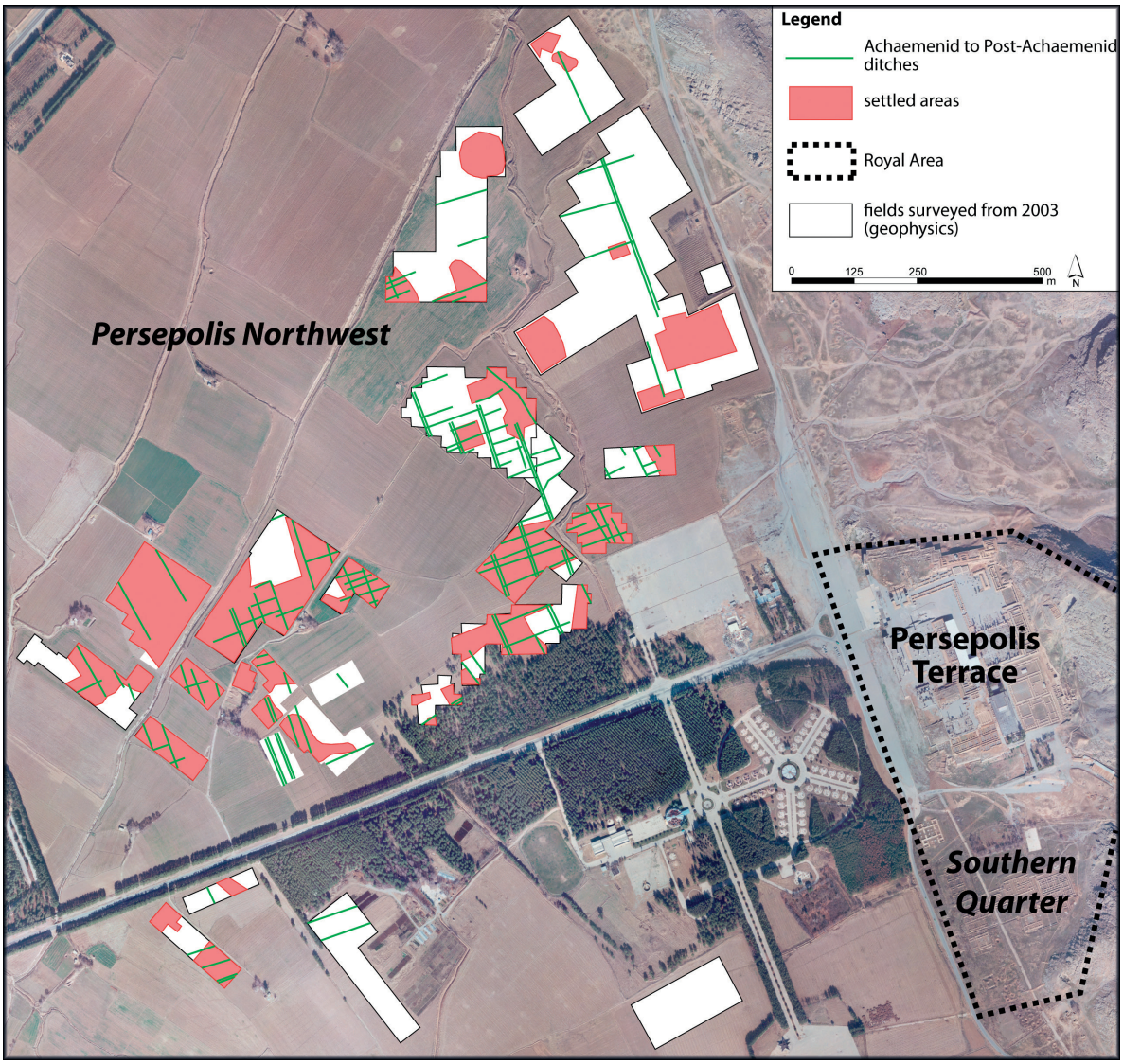

Fig. 2. Layout of Achaemenid to Post-Achaemenid remains in the Persepolis Northwest area west of the Persepolis Terrace, reconstructed thanks to the results of the Iranian-French (2005-2008) and Iranian-Italian (2008-present) archaeological projects (adapted from Gondet, Mohammadkhani, Askari Chaverdi 2018: 3-Fig. 1, with modifications; CAD S. Gondet).

2. Data on Persepolis seen as an agrarian area and on its development chronology

Data published in the last decades from textual and archaeological sources prove that the lands around the terrace of Persepolis were fertile and intensively cultivated during the Achaemenid period[12]. Recent articles based mainly on the analysis of two tablets from the administrative archives of Persepolis[13] provide insights into the nature of agricultural development around the Royal Area. They show that thousands of fruit trees, of various species, were planted in the Persepolis region during the reign of Darius[14]. They also demonstrate that the trees were cultivated and the harvested fruit was stored in plantations located close to Persepolis[15]. Data from the archives allow one to be more precise about the nature of some of the lands left unbuilt within the Persepolis Settled Zone, an area that among other crops included large orchards. When looking at the number of trees recorded and considering the large quantity of fruits possibly produced, the archives reveal a deliberate strategy of the administration to build and maintain significant farming facilities at Persepolis[16]. As discussed extensively in the above-mentioned publications, the development of arboriculture in the Persepolis region echoes palaeobotanical analyses of pollen trapped in the sediment archives of Lake Maharlu located in the south part of the Shiraz sedimentary basin (Fig. 3a). A first analysis hypothesized a peak of pollens of cultivated trees during the 1st millennium BC[17]. A recent revision of the chronology of the sediment deposits in lake Maharlu[18] dates the peak to the late Sasanian/Early Islamic period[19]. The results nevertheless show that cultivation of various species of trees and the grapevine in the region began as early as the Pre-Achaemenid/Achaemenid period[20]. The data should also be interpreted in the light of the peculiar environmental condition in the Shiraz basin[21] where little is known so far on Achaemenid settlements[22]. However, the combination of textual and environmental data demonstrates a regional development of tree cultivation as from Achaemenid times. In addition to the manifold functions of the site, Persepolis may be seen as an area of intensive farming development that would have called for specific environmental conditions and land management schemes.

Regarding the area's occupational history, the study of written sources has long demonstrated that Persepolis was not an *ex-nihilo* new foundation of Darius. The Persepolis Settled Zone was at that time already populated —and probably cultivated— and the seat of an important town[23]. The Iranian-Italian archaeological work in Bagh-e Firuzi undertaken during the last decade have provided crucial contributions to this topic. The excavation of a monumental gate at Tol-e Ajori revealed the remains of a building whose plan and decorated wall faces of glazed bricks are similar to those of the Neo-Babylonian Ishtar Gate at Babylon[24].

[12] Root 2015: 13; Boucharlat 2020: 65. Review of textual evidence on efforts related to cultivation in the Persepolis region, see Henkelman 2021: 133-136.

[13] Henkelman, Stolper 2021; Henkelman 2021; Stolper 2021; Henkelman, Kaniuth, Mohammadkhani 2023: 234-235.

[14] Henkelman, Stolper 2021: 169: Henkelman 2021: 142.

[15] Henkelman, Stolper 2021: 173: Henkelman 2021: 145-146.

[16] Henkelman, Stolper 2021: 177.

[17] Djamali *et al.* 2009; 2010.

[18] Brisset *et al.* 2019.

[19] Saeidi Ghavi Andam *et al.* 2021: 605.

[20] *ibid.*: 604-607; Djamali, Saeidi Ghavi Andam, Poschlod 2021.

[21] On the variety of climatic conditions across the Fars province, see Ricci *et al.* 2023: 85.

[22] Askari Chaverdi 2023 provides data concerning Achaemenid occupation at a site located north of Shiraz.

[23] Briant 1996: 99. Detailed review of all the available data on this topic in Askari Chaverdi, Callieri 2020: 196-198. Concerning archaeology, see comments of Sumner 1986: 28 and a review of the data on the Firuzi area available before the launching of the Iranian-Italian project in Boucharlat, De Schacht, Gondet 2012: 264-267.

[24] The team has regularly reported on the results of archaeological campaigns at and around Tol-e Ajori in Askari Chaverdi, Callieri, Gondet 2013; Askari Chaverdi, Callieri, Matin 2014; 2017. Summary in Askari Chaverdi, Callieri 2020: 186-196.

Surveys undertaken and trenches excavated at and between surrounding sites demonstrated that the gate was part of larger monumental complex that followed an open layout akin to that defined at Pasargadae[25]. The spaces between buildings, located several hundreds of meters from one another, are crossed by parallel ditches sharing the same orientation as the constructed features. As at Persepolis Northwest, the Bagh-e Firuzi area was equipped with drainage facilities. Based on the gathering of chronological evidence, both relative and absolute, the foundation of the Bagh-e Firuzi complex is dated to the Early Achaemenid period, therefore predating the terrace's construction[26]. Moreover, the orientations of buildings and drainage facilities between Bagh-e Firuzi and Persepolis Northwest/Royal Ara are different. They result certainly from two distinct phases of land development[27]. In Early Achaemenid times, a first nucleus associating town and monumental complex may have existed in the Firuzi area[28], and during the reign of Darius, the core of the Persepolis Settled Zone was shifted 3km to the east. This displacement represents a deep change in the occupational history of the micro-region during the Achaemenid period, a change with obvious political and historical meanings, which could also be read in terms of environmental factors.

3. Environment setting of Persepolis: overview

One of the intermontane basins along the Zagros chain in Southwestern Iran, which are favourable regions for settlement and farming[29], the Persepolis plain shows some of the best potential for agricultural development[30]. Surrounded by limestone ranges, the plain is a northwest–southeast oriented sedimentary basin more than 100km long and 30km wide (Fig. 3a)[31]. Consequently, the region was able to supply a large number of fields for crops. The mean altitude of the plain is above 1600m —1610m at the foot of the Persepolis Terrace — and its slope gradient is low (less than 0.06%)[32]. The climate of the Persepolis region is semi-arid and defined as continental Mediterranean with a strong influence of altitude[33]. It is characterized by high inter-seasonal variability with cold and humid winters and long dry seasons lasting up to 8 months, marked by hot summers. Records of rainfall demonstrate a climatic gradient across the plain, annual mean precipitation value being 448mm at Dorudzan in the northwest and 199mm at Neyriz in the southeast (Fig. 3b)[34]. At Marvdasht, not far from the Persepolis

[25] Gondet 2018: 201; Boucharlat 2020: 41, 65; Askari Chaverdi, Callieri 2020: 199. On the morphology and the layout of Pasargadae, based on archaeological work carried out as from the late 1990s, see Benech, Boucharlat, Gondet 2012; Boucharlat 2014; Gondet 2018: 193-197; Gondet *et al.* 2019; 2021.

[26] Askari Chaverdi, Callieri 2020: 196-200.

[27] Boucharlat, De Schacht, Gondet 2012: 267; Gondet 2018: 201; Askari Chaverdi, Callieri 2020: 196; Callieri: 2022: 131-132.

[28] The existence of another early nucleus at Dasht-e Gohar (Fig. 1) is also presumed. In the absence of firm new evidence on the chronology and the nature of the occupation in this area, Dasht-e Gohar has not been integrated into the present development scenario of the Persepolis Settled Zone. See Boucharlat, De Schacht, Gondet 2012: 258 on the difficulties in interpreting results of surveys carried out at this location. For reviews on the data available for the Dasht-e Gohar complex, see: Bessac, Boucharlat 2010: 30-36; Askari Chaverdi, Callieri 2020: 199.

[29] Planhol 2000; Kehl, Rafiei-Alavi, Alizadeh Ketek Lahijani 2023: 22; Ricci *et al.* 2023: 85.

[30] Kortum 1976: 257; Moameni 1999: 73; Hartnell 2014: 183-185; Caiserman, Amiraslani, Dumas 2021: 1.

[31] Overview of the physical and environmental setting of the plain in: Kortum 1976: 31-68; Moameni 1999: 5-16; Kehl, Frechen, Skowronek 2009: 58-61; Djamali *et al.* 2018: 1159-1161. See also Gondet 2011: 31-88 which, updated with recent publications, provides part of the material used in this article.

[32] Kehl, Frechen, Skowronek 2009: 58; Djamali *et al.* 2018: 1159.

[33] Rigot 2010: 62-63; Djamali *et al.* 2018: 1159; Caiserman, Amiraslani, Dumas 2021: 2; Rigot *et al.* 2022: 85.

[34] Until the early 2010s, the data for the Dorudzan and the Neyriz stations were available on the website of the Iranian Meteorological Organization for the period 1961-2000 (http://www.irimo.ir). The website is no longer accessible. The data for the years 1990-2017 published by Caiserman, Amiraslani, Dumas 2021: 2 provide almost the same values.

Terrace, mean annual rainfall is about 330mm[35]. The Kur river is the mainstem draining the plain from northwest to southeast, from the Dorudzan area upstream towards the playa complex of lakes Tashk and Bakhtegan downstream. The Pulvar river[36] is its main tributary, flowing from the northeast and the Pasargadae region, crosses the Persepolis Settled Zone, and joins the Kur southwest of the modern city of Marvdasht. The value of the Kur's annual discharge is much higher than the Pulvar's[37], defining from afar the Kur as the principal stream draining and watering the Persepolis plain. Karstic springs are also a major component of the regional hydrosystem; at least 148 springs are recorded on the 1:25000 topographic maps of the region, and among them 14 main springs or complexes of springs have been detected[38].

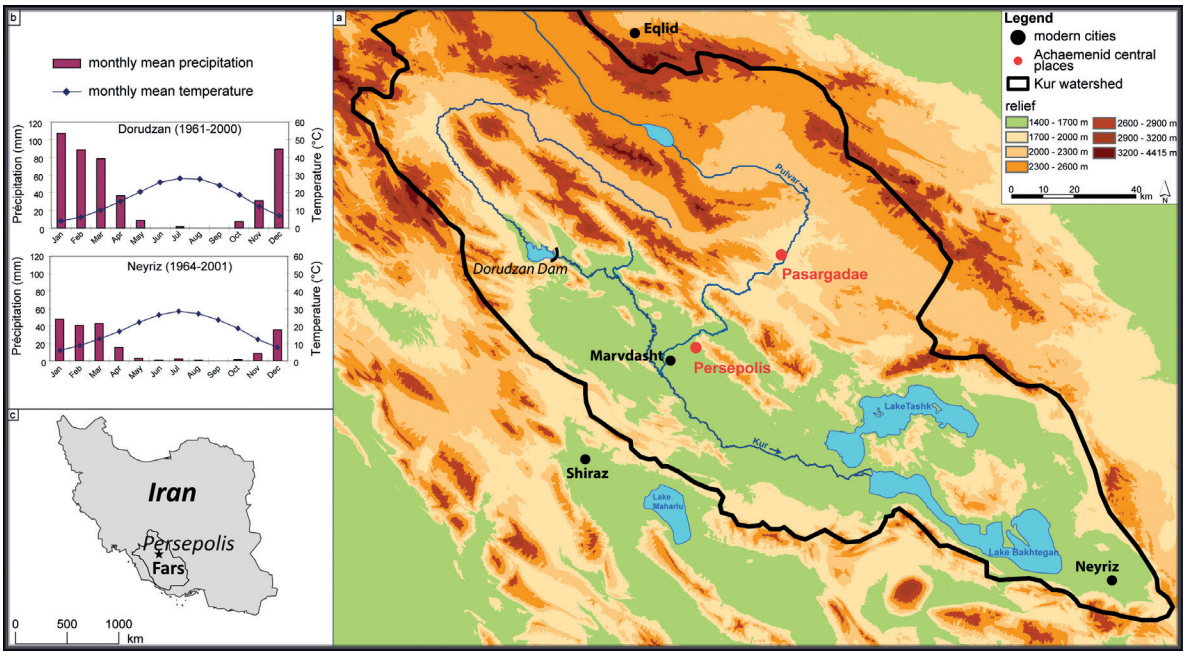

Fig. 3. Environmental setting of the Persepolis plain. (a) Physical map and hydrography; (b) Ombrothermic diagrams for the north (above) and south sectors (below) of the plain; (c) Location of the studied area (ASTER STRM for the terrain basemap; IRIMO for climatic data; CAD S. Gondet).

We shall take a closer look at the Persepolis Settled Zone and the palaeoenvironment of the plain during the Achaemenid period. From a geographical point of view, its position is strategic, since it is located at the outlet of the Pulvar river in the Persepolis Plain and at the intersection of two natural circulation highways, i.e. the northwest/southeast Kur basin and the southwest/northeast Pulvar valley. The natural landscape of the area contributed various resources to Persepolis. Surrounding by mountain ranges, providing construction materials like stone[39] and wood, as well as extensive pastures[40], the Persepolis Settled Zone includes wide spaces of flat lands available for agricultural activities. The plain's present environmental and climatic conditions, as detailed above, are suitable for the development of agriculture,

[35] Moameni 1999: 8.

[36] According to vernacular toponymy, it is alternatively called the Sivand when it reaches the valley upstream of the Persepolis plain. See Duva 2018 for a review of the names given to the rivers of the region according to various historical sources.

[37] 30 times higher in Kortum 1976: 50-51; 15 times higher in Moameni 1999: 14.

[38] Djamali *et al.* 2018: 1161-1163.

[39] Gondet 2015.

[40] Saeidi Ghavi Andam *et al.* 2021: 601-603 on proxy data from the Maharlu sedimentary archives relating to intensification of pastoral activities and deforestation as from the 1st millennium BC.

but subject to several constraints. The main one relates to water availability. Although present mean annual rainfall values allow dry agriculture, precipitations are unevenly distributed over the year. According to recent paleoclimatic reconstructions, seasonal variability affected Southwestern Iran during the entire Holocene and consequently in the Achaemenid period[41]. Yet during the Holocene, climatic changes occurred in the amount and yearly distribution of precipitations. Their reconstruction may vary according to the nature and location of studied palaeoenvironmental archives[42]. In the Central Fars area, the Achaemenid period would have been a long phase of lower aridity and fairly stable hydro-climatic conditions[43]. While probably carried out in more favourable conditions, farming activities during the Achaemenid period required irrigation, especially in the spring and the summer seasons. This is illustrated by archaeological data gathered in the Pasargadae and Persepolis regions, which attest the development on a regional scale of large hydraulic infrastructure during the Achaemenid period to tap water from the various local resources[44]. In addition to water, agrarian development also needs suitable croplands to cultivate and harvest desired species. In the following sections of this article, a closer look at soil fertility will permit a better definition of the agrarian potential in the Persepolis Settled Zone and explanations on how it was managed during the Achaemenid period. This is combined with a review of data recently obtained on the Pulvar river's morphology in the past, with consequences for the hydrographic context of agricultural activities in the Persepolis area, and possibly for its occupational history.

4. Regional soil conditions, consequences for land improvement and land-use at Persepolis

Since the Persepolis Plain was a strategic region for agricultural production in Fars, it was subjected to large land development programs and farming intensification, mainly linked to the construction in the early 1970s of a reservoir dam across the river Kur, upstream from the plain at Dorudzan (Fig. 3a). As from that date, pre-existing land-use patterns have deeply changed, and the present state of the agrarian landscape differs almost entirely from the pre-existing traditional one[45]. This project of development was preceded by precise surveys of the plain's agricultural potential and, among other features, the soil's properties[46]. The soil map drawn on this occasion (Fig. 4) provides an overview of potential cropland quality over a surface of about 100,000ha in the northwestern part of the Persepolis plain. This document is an inventory of soil conditions prior to agricultural intensification in the last decades. Its analysis is of great utility for the reconstruction of large-scale land-use patterns in the past and for defining agrarian potential in the Persepolis Settled Zone. While at present appearing

[41] Rigot *et al.* 2022: 98.

[42] Kehl, Rafiei-Alavi, Alizadeh Ketek Lahijani 2023: 26-29.

[43] Saeidi Ghavi Andam *et al.* 2021: 601; Rigot *et al.* 2022: 99; Ricci *et al.* 2023: 86. See Matthews, Fazeli Nashli 2022: 396-398, 497-498 assessing suitable climatic conditions in the Iron Age, based on an overview of the palaeoenvironmental data available for the large Southwest Asia region. This general view is, however, counterbalanced by the occurrence of a possible episode of drier climate around 550 BC, recorded in the archives of the Maharlu lake, see Ricci *et al.* 2023: 88. This result clearly demonstrates the rapid and localized climate changes that may have occurred during the Late Holocene, as discussed by Kehl, Rafiei-Alavi, Alizadeh Ketek Lahijani 2023.

[44] Boucharlat, De Schacht, Gondet 2012; De Schacht *et al.* 2012; De Schacht 2018; Shobairi 2018; Chambrade *et al.* 2020.

[45] Kortum 1976: 237-250; Moameni 1999: 75-84. On modern changes in the landscape and their consequences on the archaeology, see Boucharlat, De Schacht, Gondet 2012: 254-257.

[46] Justin, Courtney 1966 provides a comprehensive report which has been extensively used by Kortum 1976; Moameni 1999. Kehl, Frechen, Skowronek 2009: 59-Fig. 2 published another version of a soil map of the area based on survey of the early 1970s.

as a large fertile region entirely covered by croplands, the Persepolis plain has to cope with several constraints for agriculture. They are mainly linked to the low slope gradient and slow permeability of soils, which imply a shallow groundwater table, the presence of large swamps and extensive problems of salinization[47].

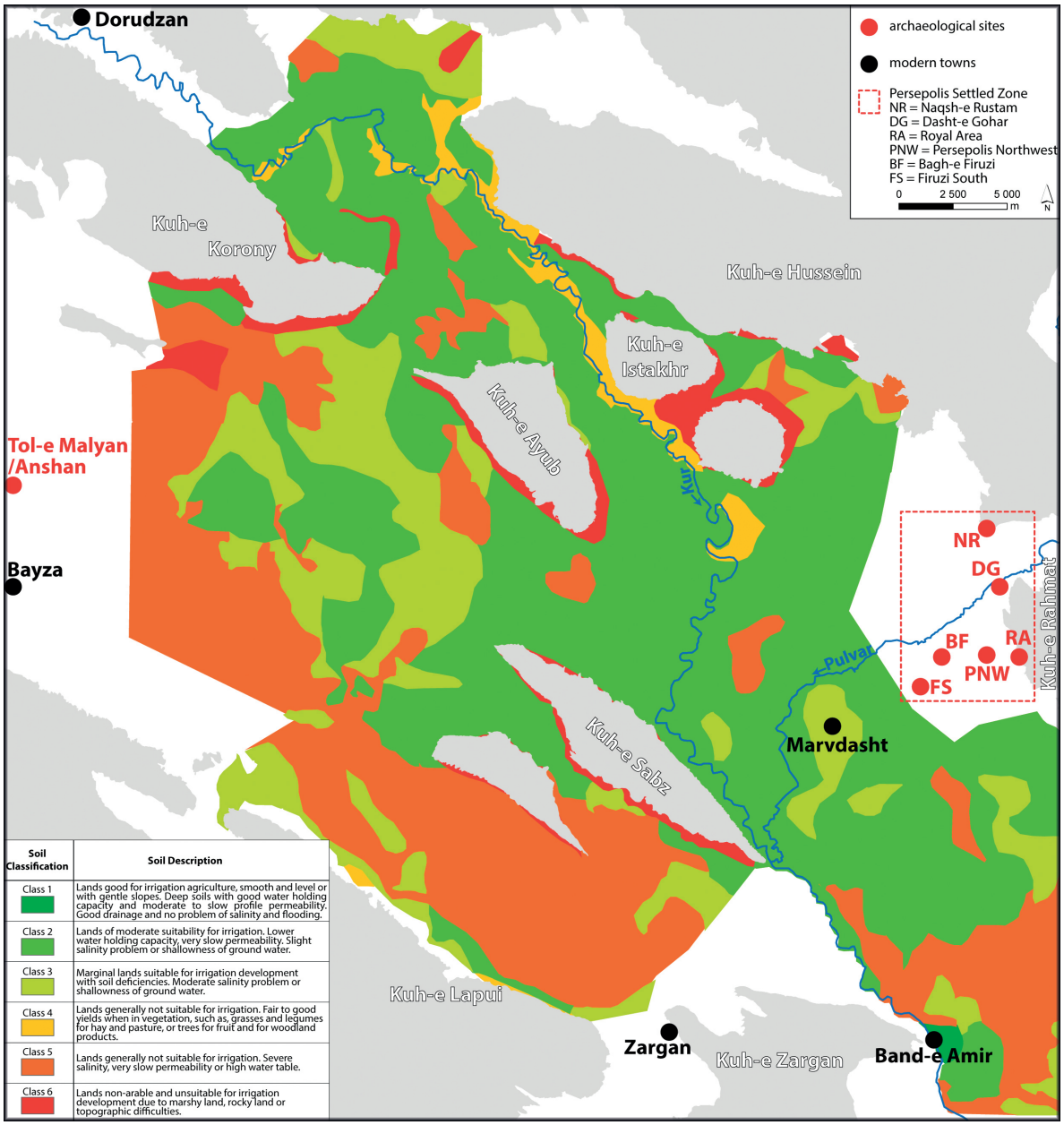

Fig. 4. Soil map and description in the northwestern part of the Persepolis plain (adapted from Justin & Courtney 1966, with modifications; CAD S. Gondet).

West and south of Persepolis, large areas of lands are described as non-arable because of slow permeability, salinization, and waterlogging issues (Class 5 on Fig. 4)[48]. These regions correspond for the most part to large swampy areas, which were dominant elements of the landscape before the modern campaigns of extensive drainage, linked to the new irrigation scheme designed following the Dorudzan dam's construction. In the region of the modern town of Bayza northwest of the Persepolis plain, the landscape was dominated

[47] Kortum 1976: 33; Moameni 1999: 11-12; Kehl, Frechen, Skowronek 2009; Djamali *et al.* 2018.
[48] Justin, Courtney 1996: D-17.

by swamps, which are a result of the combination of shallow groundwater and clusters of karstic springs[49]. The wetlands, which extended over several square kilometres[50], have poor agricultural potential but may have been of economic interest, as demonstrated by studies on Anshan, the Bronze Age Elamite capital of the Iranian highlands. Whether the Bronze Age city's economy was mainly based on farming, datasets have shown the growing interest of its inhabitants in resources of the surrounding wetlands —i.e. aquatic plants and waterfowls— as well as in water supplied by the numerous springs (given that the site is located far from the main rivers)[51]. The southeastern part of the plain has been environmentally speaking less studied than the northwest, because it is considered as less fertile. It comprises large areas of salty and swampy lands surrounding the complex of shallow and semi-permanent saline lakes of Tashk and Bakhtegan (Fig. 3a). This general statement should be balanced by archaeological data, which show for instance that several Late Bronze Age settlements were distributed along the Kuh-e Rahmat range southeast of Persepolis[52]. The western part of the southeastern plain has also been subjected to agricultural development since at least the Sasanid/Early-Islamic era, as seen in the construction of a diversion dam across the Kur river at Band-e Amir; this dam supplies networks of canals located downstream[53]. In the vicinity of Band-e Amir, several Achaemenid sites were recorded in the past but have certainly been destroyed[54]. It is still true nonetheless that large amounts of land located southeast of the plain have poor soil quality, due to the combined effects of lower slope gradient, shallow water tables, flow of spring water with high saline content[55], resulting in a process of extensive salinization of soils. These instances of apparently barren lands dominating the plain's south-eastern part may have rather been suitable for extensive pastoralism, but not for intensive farming activities in the absence of considerable drainage and irrigation projects[56].

When compared to Bronze Age Anshan, the foundation of Persepolis in the central part of the plain reflects a change in regional occupational history. The Persepolis Settled Zone was part of a large area of lands suitable for irrigation and crop production (Class 2 soil around the Persepolis Settled Zone on Fig. 4). The micro-region is also crossed by the river Pulvar, which provides large and perennial amounts of water. Located in the most fertile part of the plain, between the extensive wetlands in the northwest and the salty lands in the southeast, the Persepolis Settled Zone's natural landscape provides good conditions for an intensive and extensive development of agriculture (Fig. 5). Farming activities in the area face several difficulties, however. The soil survey has characterized the land surrounding the area as having slow permeability, a shallow water table, and a slight salinity problem[57]. Intensive agricultural production hence demands irrigation and well-developed drainage facilities. Considering soil conditions in the Persepolis Settled Zone, the network of ditches recorded at Persepolis Northwest and Bagh-e Firuzi (Fig. 2 and Fig. 6) seems essential to improve farming productivity. It provided water for people and irrigation and, above all, drained excess water and the shallow ground water whose stagnancy

[49] Djamali *et al.* 2018.
[50] Cornwallis 1968 provides an inventory of the wetlands in the region and p. 154-155 assesses the swampy lands along the southwestern Kuh-e Lapui range to be to 120 km² in area. Kortum 1976: 32 gives almost the same estimation for this large wetland.
[51] Djamali *et al.* 2018: 1168-1169.
[52] Sumner 1994.
[53] Hartnell 2014: 196-199; Duva 2018: 107-108.
[54] Sumner 1986: 9-10. See also Djamali *et al.* 2018: 1169-1170 on the remains of a supposed Achaemenid reservoir dam near the north-western shore of Lake Tashk.
[55] *ibid.*: 1169.
[56] Kortum 1976: 33-34.
[57] Justin, Courtney 1966: D-16. Moameni 1999: 148 underlines that more than 50% of the lands in the plain's northwestern part are affected by salinization.

could increase salinization[58]. In addition, the crop evapotranspiration during spring and summer could also play a significant role into the salinization process, as well as on having an influence on the balance between water availability and consumption[59]. Taking into account present climatic regional conditions, it has been demonstrated that orchards are the most suitable crop to reduce the effects of the evaporation[60]. This result is echoed by the focus on arboriculture during the Achaemenid period documented by textual and palaeoenvironmental studies, since orchard cultivation appears as cropland particularly well-adapted to the environmental conditions of the Persepolis region.

Fig. 5. View, from the Kuh-e Rahmat slope southwest of the Persepolis terrace, of the surrounding cultivated plain (S. Gondet, fall of 2005).

5. Hydrographic conditions at Persepolis during the Achaemenid period: consequences on water availability and occupational history

The Persepolis Settled Zone includes various hydraulic installations[61]. In the Royal Area, drainage networks protected the constructions from washout and diverted the water to cisterns and tanks[62]. These hydraulic facilities are related to a local use for people living in the Royal Area and for the gardens that probably surrounded the monuments. Further away, the

[58] Boucharlat, De Schacht, Gondet 2012: 256, 278-279 have already suggested dual functions for the networks of ditches. See also the general remarks in Matthews, Fazeli Nashli 2022: 398 on the impact of intensive agricultural production on soil salinity during the early imperial period.
[59] Caiserman, Amiraslani, Dumas 2021.
[60] *ibid.*: 9.
[61] Boucharlat, De Schacht, Gondet 2012: 276-279.
[62] See Mousavi 2012 for a description and related bibliography concerning the drainage systems on the terrace, on the Kuh-e Rahmat slope, and in the Southern Quarter. Asadi 2018 has published a report on the recent excavation of the drainage system in the south part of the terrace.

water used for the settlements and the croplands were certainly supplied through the networks of ditches mapped at Persepolis Northwest and Bagh-e Firuzi. The origin of the water and the channels through which it was drained towards the networks of ditches is currently under discussion. Recent results on the reconstruction of the Pulvar river's dynamics during the Holocene provide a new frame to look deeper into this topic. Today the Pulvar river flows in the Persepolis region at some 11m under the level of the plain floor at Bagh-e Firuzi and at about 15m under near Istakhr (Fig. 6). Study of the thick alluvial deposits in the Pasargadae region, upstream from Persepolis, has demonstrated that the Pulvar riverbed was certainly less incised in the floor of the sedimentary basins during the Achaemenid period than it is today[63]. The absolute luminescence dating obtained on several Pulvar sedimentary sequences leads to the suggestion that the main phase of river incision began at the turn of the 1st millennium BC.[64]. Regarding the data obtained in the Pasargadae region, it is likely that the flow level of the Pulvar in the Persepolis plain was also higher during the Achaemenid period. Although this hypothesis needs to be confirmed by precise analysis of the Pulvar deposits in the Persepolis plain[65], it should be taken into consideration when considering water availability in the Persepolis Settled Zone. It could also provide elements of context relevant to discussion of the region's occupational history.

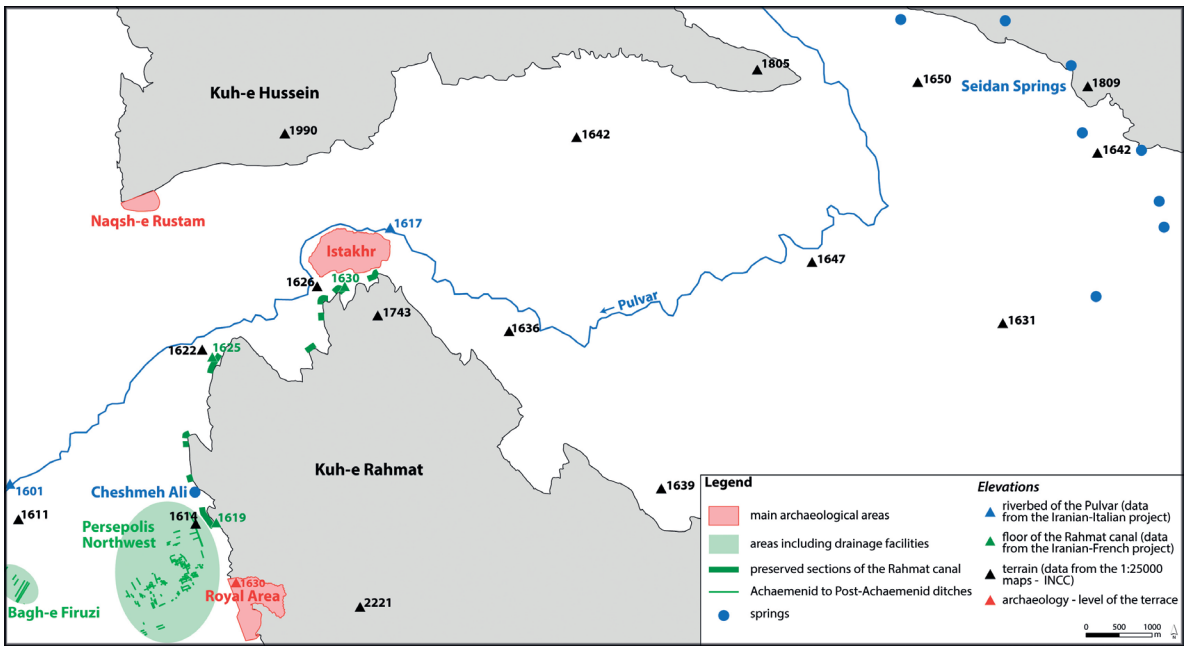

Fig. 6. Map of water resources and hydraulic installations in the Persepolis Settled Zone, with elevations of the terrain and some features related to the waterscape; CAD (S. Gondet).

It has been suggested that the drainage network in the Persepolis Northwest area was supplied with water via the open-air canal of which preserved sections, mainly rock-cut, are

[63] Rigot *et al.* 2022. This result allows one to refine previous geomorphological studies, suggesting that the Pulvar was already deeply incised during the Achaemenid period, cf. Kehl, Frechen, Skowronek 2009; Rigot 2010; De Schacht *et al.* 2012; Boucharlat, De Schacht, Gondet 2012: 277; Boucharlat 2020: 66-67. The hypothesis was also based also on the historic account of Quintus Curtius Rufus, *Alex*, 5.4.7 on the geography of Fars describing the Pulvar as "[…] sunk deep in the soil […]". But, as Duva 2018: 110 emphasizes, the river which he describes may probably not be the Pulvar.

[64] Rigot *et al.* 2022: 97.

[65] See the discussion in *ibid.*: 97-98 on the differences in results and hypotheses between earlier and most recent studies on changes in the Pulvar river during the Holocene. They could be linked to differences in river dynamics from one sedimentary basin to another.

known to run along the Kuh-e Rahmat foothills, from the site of Istakhr towards the terrace (Fig. 7)[66]. The geophysical survey carried out in the fields along the foothill and north of the terrace has not revealed a connection between the network of ditches and the canal. The construction of an asphalted road and the digging of *qanats* —wells and related underground aqueducts— probably of later date than the Achaemenid period, have certainly destroyed the remains of earlier hydraulic infrastructures[67]. The canal's relative dating can be surmised when considering the fact that upstream, next to the site of Istakhr, it is associated with an enigmatic construction made of finely cut ashlars probably dating to the Achaemenid period. As a matter of fact, the location and the route taken by the canal constitute the most robust evidence for its use in supplying the drainage facilities in the Persepolis Northwest area. It ran along and above the fields sprawling along the Kuh-e Rahmat foothills, and was thus suitable for providing water for irrigating them. The question of the water's origin (i.e. the canal's intake) must consider the canal's topographical location on the foothills, between 4m and 7m higher than level of the plain (Fig. 7). If one looks at the Pulvar's present morphology, one notices it is incised more than 10m deeper under the mean valley floor level, and it would seem unlikely that the canal was connected to the Pulvar. The analysis of old satellite imagery has led our team to suggest, therefore, that the water for the canal was drained from the complex of karstic springs complex, located 10km east of Istakhr near the modern village of Seidan (Fig. 6)[68].

Fig. 7. View from the west of a rock-cut section of the Kuh-e Rahmat canal located southwest of Istakhr. Note its bottom, lying several meters higher than the plain on the left (S. Gondet, spring 2005).

[66] Boucharlat, De Schacht, Gondet 2012: 276-279. Based on the analysis of maps published in the 19th century, Shobairi 2018: 153 and Boucharlat 2020: 65-67 suggest that the water would have been supplied by a canal connected to the Pulvar and running across the flat lands along the Kuh-e Rahmat. The canal, which has vanished today, diverted the water from the river, whose bed was incised, and raised it to the level of the floor of the plain. The canal corresponds to an irrigation scheme adapted to the hydrographic conditions of the 19th century. According to the data obtained on the changes in the Pulvar, the conditions would have been different during the Achaemenid period. The higher flow level would have permitted to build canals at higher topographic level. See discussion on modern irrigation scheme versus morphology of the Achaemenid networks in the plain of Pasargadae in Rigot *et al.* 2022: 91-92.

[67] Gondet, Mohammadkhani 2017: 21-22.

[68] Boucharlat, De Schacht, Gondet 2012: 277-278. Moradi-Jalal *et al.* 2010 make the same assumption.

Since the Pulvar was probably less incised in the Achaemenid period, the hypothesis of a canal intake site in the riverbed should nevertheless be reconsidered under the proviso that a diversion dam was erected across the river upstream from the Kuh-e Rahmat[69]. However, the role of the karstic springs for the Persepolis Settled Zone's water supply, from the Seidan area or closer to the terrace from Cheshmeh Ali (Fig. 6)[70], deserves our continued attention. A recent study on the karstic springs undertaken at a regional scale has demonstrated that they were an important source of fresh water during the entire Holocene[71]. The origin of the water for irrigating croplands in the Persepolis Settled Zone remains an open question, and the choice to use hydrological resources from the river or from the karstic springs would have depended on the quality and the amount of water available, as well as on its suitability as regards the soil conditions. The use of water with less mineral content would be more suitable for preventing the process of salinization. Further analysis of present-day water quality and of the sedimentary archives next to the springs could be useful for a more objective approach to these matters.

When compared to the Persepolis Northwest and Royal areas, Bagh-e Firuzi is closer to the Pulvar and to perennial water resources[72]. Water was certainly directly supplied to the area from the streambed, quite easily in fact since it would have been less incised. Further survey over the fields located between Bagh-e Firuzi and the Pulvar may provide data on the connection of the old drainage network with the river. The higher level of the Pulvar flow would also put the Firuzi area at a higher risk of frequent flooding[73]. The choice of the Kuh-e Rahmat foothills for a monumental new complex placed at a higher elevation and further away from the Pulvar might have also been aimed at protecting constructions from the river's overflow. Bagh-e Firuzi would have been regularly exposed to natural hazards[74] that could partly explain the shift of the main monumental core of Persepolis 3km to the east. Further studies of the Pulvar alluvial sequence in the Persepolis Settled Zone, particularly at Bagh-e Firuzi, could provide data on the frequency of flooding episodes in the region. Taking the environmental setting into consideration could contribute to the definition of the Persepolis' occupational history, i.e. the issues of the abandonment of Bagh-e Firuzi or the coexistence of two monumental complexes during the Achaemenid period.

6. Advantages and constraints of the setting of Persepolis: remarks and perspectives for future research

An overview of the Persepolis region's environmental setting shows that choice of location of the Achaemenid centre was probably partly driven by the project to develop intensive farming in the vicinity. The agrarian function of much of the lands of Parsa —alternately the Persepolis Settled Zone or the Persepolis region— is proven by the administrative archives dealing with arboriculture and by the archaeology revealing a loosely built-up landscape around the terrace complex, with large areas left available for croplands.

[69] Malekzadeh 2007 publishes evidence of several dams along the Pulvar valley, but they are not precisely located.

[70] On the possible role of Cheshmeh Ali in the water supply, see observations of Shobairi 2018: 153-154 and Boucharlat 2020: 65-66. The geophysical survey undertaken in the area has shown evidence of hydraulic installations connected to the spring, but these are certainly later than the Achaemenid period, cf. Gondet, Mohammadkhani 2017: 21-22.

[71] Djamali *et al.* 2018. See also Moradi-Jalal *et al.* 2010: 92-94 for estimation of the present outflow of springs near Seidan.

[72] Boucharlat 2020: 61.

[73] Saeidi Ghavi Andam *et al.* 2021: 601 record frequent floods during the Mid- to Late Elamite periods in the Shiraz basin.

[74] Along with possible flooding, Askari Chaverdi, Callieri, Matin 2017: 227-228 have published evidence of an earthquake event, which occurred in the earliest occupational phases of the building excavated at Tol-e Ajori.

The area of the Persepolis Settled Zone includes the region's most fertile lands, as well as various water resources. Paleoenvironmental studies have shown that during the Achaemenid period, the climate was rather favourable to the development of agriculture, and that water was more easily accessible than today since the flow level in streams was probably higher. This setting was also subject to many constraints. Soil properties, combined to semi-arid climatic conditions, warranted careful management of irrigation and efficient drainage, in order to secure crop yields and prevent the onset of salinization. The networks of ditches, revealed in the Persepolis Settled Zone or the Bagh-e Firuzi area, were suitable drainage facilities for optimal land-use during the Achaemenid period. The suitability of the Achaemenid land-use pattern is also demonstrated by its resilience, as it would have been maintained long after the fall of the empire[75]. Moreover, the Pulvar's hypothetical lower incision would have resulted in more frequent episodes of flooding, which could have affected the Early Achaemenid Bagh-e Firuzi cluster of monumental constructions located next to the riverbed. At the time of Darius, the choice to create the new terrace complex several kilometres further east, at an elevated position and at the edge of the floodplain, may have been partly driven by hydrographic conditions during the Achaemenid period.

The large-scale development project of Persepolis deserves to be analysed by considering its environmental setting. Soil conditions, water availability and quality, hydrography and past land-use patterns are all topics that would require further combined investigations of sedimentary archives and archaeological remains[76]. Judging from the variability of the environmental conditions at the scale of the Persepolis basin and, more broadly, from one sedimentary basin to another across the Fars, further pluridisciplinary studies should focus on the micro-regional scale of the Persepolis Settled Zone to gather data relevant on setting and impact of its development[77].

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[75] There is evidence of Post-Achaemenid occupation and continuity in land-use pattern in the Persepolis Settled Zone; see a review in Callieri, Askari Chaverdi 2013: 700-705. Recent data on the Post-Achaemenid occupation and land-use of the area are available in Askari Chaverdi, Callieri (eds.) 2017 and summarised in Gondet, Mohammadkhani, Askari Chaverdi 2018: 25-29; Askari Chaverdi, Callieri 2020: 182-183; Matthews, Fazeli Nashli 2022: 480. See also Henkelman 2021: 148 and Henkelman, Kaniuth, Mohammadkhani 2023: 242 on the resilience of the Persepolitan economy based on agricultural production. Palaeobotanical data in the Shiraz basin, published by Saeidi Ghavi Andam *et al.* 2021 place the Achaemenid period within a longer era of increasing farming activities extending from the Elamite to the Islamic period.

[76] "[…] we are only at the beginning of our understanding of the city of Pārsa […]" as observed by Askari Chaverdi, Callieri 2020: 199. See the presentation and the objectives goals of a recently launched project focusing on the Firuzi area in Colliva, Matin 2023.

[77] See discussions of Djamali *et al.* 2018: 1171; Rigot *et al.* 2022: 101; Kehl, Rafiei-Alavi, Alizadeh Ketek Lahijani 2023: 27 on the needs of further paleoenvironmental studies in Fars focusing on the local scale.

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