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Article

A Look Back at the Irrigated Areas of the Medieval Town of Tāmdult (Morocco)

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Abstract

From the 9th century onwards, Tāmdult was one of the three major caravan ports in western Maghreb, alongside Sijilmāssa and Nūl Lamṭa. By the mid-20th century, the remains of dwellings, metallurgical production sites and fortifications had been located a few kilometres south of the present-day oasis of Aqqa, which is irrigated by the resurgence of the wadi of the same name. In 1999, our research, which was based on field surveys and aerial photographs, revealed exceptionally well-preserved traces of a large-scale agricultural system and an irrigation canal network adjacent to the ruins. This completed the picture of this pre-Saharan oasis. An initial study was published in 2011. However, the question of the chronological relationship between the two oases, Tāmdult and Aqqa, remained unresolved. Processing recent satellite images (Airbus © 2023) of these two oases and creating a WebGIS interface now enables us to refine and correct our observations from 1999. This new data largely confirms our initial proposals, such as the joint development of an urban settlement and an agricultural area with an irrigation network. Furthermore, these new images show the branching structure of the various water distribution channels, the regularity of the agricultural land parcels and the existence of interstitial rural settlements. They thus reveal a hierarchy in this distribution that was perhaps insufficiently explored in our initial publication. Given the limited historical sources available, we can now make more informed arguments regarding the possibility of the two oases coexisting over time. We can also propose initial hypotheses about the main reasons for the abandonment of one of the oases and discuss the identity of their founders, which could be local tribal groups and/or branches of the Idrisid dynasty. The central issue of the dossier to which our contribution is addressed — 'The Role of Urban Elites in the Construction of Rural Landscape' — is adapted here to the specific characteristics of the pre-Saharan context in terms of both climate and settlement structure.

Keywords: urban genesis; image processing; webGIS; irrigated land parcels; hydraulic networks; urban/rural relations; pre-Saharan oasis spaces

Introduction

This article is a kind of codicil to an unfinished project, *The Genesis of the Islamic Town in Morocco: Nakūr, Aġmāt, Tāmdult.* This Moroccan-French cooperation programme, co-directed from 1995 to 1999 by one of us, together with E. Erbati (INSAP, Rabat), aimed to highlight the processes of urban genesis in the western Maghreb during the emergence of the first autonomous states in the 8th-9th centuries, based on three emblematic cases from different geographical contexts: Nakūr on the Rif coast (Himyari emirate, Mediterranean Morocco), Aġmāt at the foothills of the High Atlas (Idrisid emirates, central Morocco) and Tāmdult, on the southern slopes of the Anti-Atlas (Idrisid governorate, Saharan Morocco). Particular attention was to be paid to how the surrounding territory and its resources were exploited, and to the impact of urbanisation on the territory. The first phase of the programme (a trial intervention at each of the three sites) was successfully carried out, but various circumstances

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prevented the second phase from going ahead, which would have involved further study of one of the three settlements and the publication of a summary of the results.

The turn of the millennium coincided with a major technological leap forward in archaeological tools. At the end of the 1990s, however, the use of digital cameras or a total station with differential measurement was far from widespread; GPS accuracy was unreliable before the end of selective availability in May 2000; satellite imagery was restricted-access material; the most detailed IGN maps of southern Morocco were at 1:100 000 scale; and the vertical aerial photographs available were at 1:75,000 and of mediocre quality. Yet despite all these handicaps, the field campaign carried out by our team at Tāmdult in 1999 proved to be particularly fruitful.

The very encouraging results, particularly concerning the irrigated area of the medieval town, led to two preliminary articles and a book chapter **[1–3]**. It now seems useful to revisit these earlier studies, both in view of the theme of this volume – the role of urban elites in the construction of rural landscapes – and with the aid of satellite imagery and WebGIS tools now available.

1. The Contribution of Written Sources

The collection of medieval sources relating to Tāmdult is not extensive, but it has the advantage of covering a fairly broad chronological range (9th-14th centuries) and of being consistent. Few geographers or chroniclers have mentioned the town: al-Ya'qūbī (9th century), Ibn Ḥawqal (10th century), al-Bakrī (11th century), the author of *Kitāb al-Istibṣār* (12th century), and finally Waṭwāṭ (14th century). One should also add a brief but important notice in the genealogies of Ibn Ḥazm (11th century). It is striking that al-Idrīsī (12th century) and Ibn Ḫaldūn (14th century), both remain silent about the town.

Al-Ya'qūbī describes Tāmdult as a dependency of Siğilmāsa, like the villages of Banū Dar'a. He notes its citadel, positions it in relation to the Sūs region, and emphasises the silver and gold mines (*ma'ādin*) – the latter said to 'grow on the surface like plants'. It was the town of the Idrisid Yaḥyā ibn Idrīs, and its inhabitants are Berbers of Banū Tarğā **[4].** Ibn Ḥawqal, for his part, merely situates Tāmdult on one of the trans-Saharan routes: 'before Lamṭa, there is Tamadalat and, further south, Awdaġust' **[5]**. Al-Bakrī **[6]** – later followed by the *Kitāb al-Istibṣār* **[7]** – is by far the most detailed. The town, located on the road from Siğilmāsa to Awdaġust, eleven days from the former and forty from the latter, was founded by 'Abd Allāh ibn Idrīs ibn Idrīs. 'A wall of stone and sun-dried brick, pierced by four gates, surrounds it and encloses two bathhouses and a busy bazaar (*sūq)*. It stands in a plain beside a river (*naḥr)* rising in a mountain some ten miles (about 18 km) away. The entire region between these two points is covered with gardens. The river powers many mills. The territory of Tāmdalt is remarkable for the fertility of its soil and the luxuriance of its vegetation, to the point that the grain yields a hundredfold.' He continues: 'Tāmdalt, a castle (*ḥiṣn)* near which there are many streams (*miyāh)* and date-palms (*naḫl)*. This stronghold is dominated by a mountain in which there is a silver mine known to the inhabitants.' The poet and genealogist Ibn Ḥazm instead attributes the town's foundation to 'Ubayd Allāh ibn Idrīs **[8]**; after debate, this version has generally been accepted by later specialists. Waṭwāṭ makes it one of the cities of Sūs al-Aqṣā, of which it forms the rampart (*qaṣaba)*, and reiterates the information about its 'watercourse', orchards, and mines **[7]**.

The image of the medieval town thus emerges clearly, though it should not be seen as static. The question of its abandonment and possible temporary revival, however, remains undistinct. It is fueled primarily by often contradictory regional traditions. According to accounts collected by B. Rosenberger and M. Naïmi **[9,10]**, internal struggles between rival population groups led to its abandonment and a mass exodus of inhabitants at the turn of the 15th century. A reoccupation, accompanied by a refortification, is said to have taken place later under the Saadian ruler Aḥmad al-Manṣūr al-Ḏahabī, to strengthen control over local tribes and the caravan route towards the Sahel. At that time, Aqqa appears to have replaced the ancient Tāmdult.

The principal points that emerge from the textual evidence about medieval Tāmdult may be summarised as follows:

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– The settlement is said to have been founded by an Idrisid, whose identity remains debated. No coins minted in the town in the name of the dynasty are known.

– It was a commercial centre at the crossroads of caravan routes (southward to Awdaġust; north-eastward to Siğilmāsa and Dar'a; and to the north, Sūs and Īglī). Tāmdult was the last urban outpost before crossing the great desert.

– The town (*madīnat*) was surrounded by ramparts (*sūr*) and contained a fortress (*ḥiṣn* or *qaṣaba*).

– It had abundant water and a flourishing oasis agriculture.

– It exploited one or more nearby silver mines, the principal source of its wealth. Mining surveys show copper metallurgy was also practised in addition to silver metallurgy.

– The circumstances and chronology of its abandonment, its possible brief Saadian restoration (16th-17th centuries), and its replacement by Aqqa remain to be clarified.

It is the fourth of these features, repeatedly emphasised in written sources, that we address here, through a new reading of our earlier field observations and their comparison with the most recent satellite imagery.

Given the ambiguities of the written sources and the partial nature of the archaeological data collected, analysis must rest on two interrelated questions: 1) Do all the remains identified at the site of Tāmdult date from the medieval period, or do they also reflect modern (Saadian) redevelopment? 2) What relationship existed between the two oases, one still alive (Aqqa, 13 km to the north-east, with a cultivated area of some 600 ha **– Figure 1–**) and the other extinct (the site studied here)? In other words: where was the Idrisid foundation located? Did the two oases operate simultaneously, and was the medieval settlement bi-nuclear?

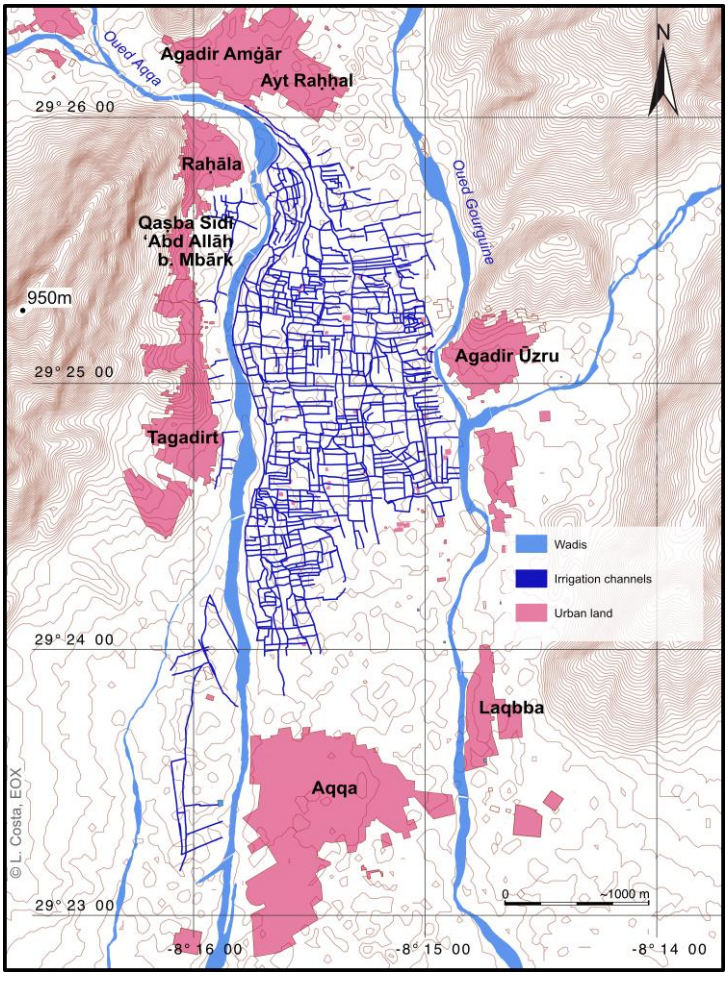

Figure 1. Current Oasis of Aqqa. Polynuclear settlement downstream of the fūm and associated hydraulic network. © L. Costa, EOX.

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2. The Historiography of Research on Tāmdult

20th-century historians and Arabists who revisited the information provided by textual sources quickly recognised the importance of Tāmdult's role in the economic history of the medieval Maghreb, but their attention focused essentially on its mineral resources and their exploitation. As early as 1936, G. S. Colin devoted an entry to it in his pioneering article on medieval mines in Morocco **[11]** (pp. 194, 196-197). The remains of the town themselves, however, were virtually unknown and, although the site had indeed been located, for several decades only brief descriptions were available, written by military personnel and administrators with an interest in history **[12–14].** These observations scarcely considered the impact of the settlement on its immediate surroundings and made no mention of the question of water.

At the turn of the 1960s-70s, B. Rosenberger drew up a very comprehensive overview of mining exploitation in medieval and modern Morocco. To do so, he no longer relied solely on textual sources but also made use of the very numerous reports by geologists filed with the Department of Mines, all documenting earlier workings; the importance of Tāmdult's former metallurgical potential is made apparent. **[15].** In a substantial article published the same year, he also presented – together with a renewed analysis of the written sources then available – the first detailed and reasoned description of the town's remains **[9].** His observations led him to emphasise 'the fourfold role of Tāmdult: defensive, mining, agricultural, and commercial' **[9]** (p. 126). For the first time, the agricultural function was explicitly mentioned, even though he did not yet recognise the vestiges of the ancient hydraulic network and its associated land parcels, which we discovered in 1999 **[1–3]** and which we reconsider in these pages.

In the years that followed, the lost town was only briefly mentioned in an inventory of the heritage of the province of Tata **[16]** (p. 63), while a very recent article with an ambitious title brought nothing new to the table – quite the contrary **[17]**. If we set aside the broader perspective offered by M. Naïmi **[10]**, who is particularly interested in the phase of Tāmdult's abandonment and the resulting changes in regional settlement, recent discussion of the town seems to have focused mainly on two themes: mining **[18–20]**, and the large Jewish community that once lived there (as evidenced by the sanctuary of Sīdī Šanāwil, preserved on the ruined site and still venerated by both Jews and Muslims) and which survived at Aqqa until the 1960s **[21,22].**

In 2018, a new Moroccan-British archaeological project was launched on Tāmdult and its region, this time within a multidisciplinary framework, led by S. Nixon and S. Mabrouk (and later Y. Bokbot). At the time of writing, a comprehensive publication of the results obtained is in preparation. So far, the *online* bulletin of the Max van Berchem Foundation (Geneva) has published a short presentation of the project **[23],** while several conferences have reported on the progress of the work. However, within this programme, the study of water resources appears to occupy only a very limited place **[24].**

It therefore now seems to us an appropriate time to revisit the issue of water at Tāmdult in contemporary terms.

3. Some Observations on Water and Urban Development in Pre-Saharan Morocco

A stable human settlement in the Saharan environment could hardly have existed without the water resources necessary for human and animal consumption and for subsistence agriculture and arboriculture. For the latter, the establishment of a system of water collection and a distribution network across irrigable plots was essential from the earliest days of the town, indeed from its very foundation **[25].** Whatever the identity of its founders, this process could not have been improvised. Moreover, although environmental constraints are obvious for the pre-Saharan and Saharan regions, the same process underpinned the founding of towns in other parts of Morocco with much less severe climatic conditions. This was the case for Nakūr (central Rif) and Aġmāt (at the foothills of the High Atlas) [**26**], both founded in the 9th century, like Tāmdult, and undoubtedly many others **[27]**.

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The three major medieval caravan towns of southern Morocco were, to varying degrees, the subject of specific research into the origins of their hydraulic systems and the plots of land they irrigated: Siğilmāsa, Tāmdult, and Nūl Lamṭa. In all three cases, the water supply system made use of surface water: these were diversions from perennial wadis, supplemented, in the case of the capital of Tafilalt, by the utilisation of the flood-spreading of biennial overflows. Contrary to popular belief (based on other regions of the Sahara), the drainage galleries (*ḫaṭṭāra*-s/ *fuggāra*-s), always late in date and interstitial in nature, played only a negligible role. The case of Siğilmāsa, studied in particular detail by Ch. Capel **[28]**, stands out for the scale of the hydraulic works carried out, which required the excavation of a veritable artificial wadi capable of carrying a considerable volume of water in a very short time and flooding the entire cultivated area simultaneously. The monumental nature of these infrastructures, considered to be contemporary with the founding of the town (mid-8th century), raises two related questions: that of the intervention of hydraulic engineers from the Near East, and that of the control of the operation by a strong political authority. At Nūl Lamṭa **[29]** as at Tāmdult, these installations are of more modest construction, yet they nonetheless include one or more diversion dams and distribution canals (*sāqiya*-s) several kilometres long.

4. A Reinterpretation of the Tāmdult Hydraulic System Through Satellite Imagery

4.1. The Satellite Images Forming the Basis of this Review: the Airbus© Mission

At the time of writing, the most recent satellite mission covering the Aqqa/Tāmdult area available on Google Earth dates from 23 May 2023. It belongs to the company Airbus©. It is this coverage of the area that has prompted the revision of our 2011 article **[**3**]**, owing to the excellent quality of the fossil traces of developments in the Tāmdult plain. These new data modify and, above all, supplement the observations and interpretations made on the area in 1999. Such optimal conditions result not only from the high definition of the imagery but also from the combination of climatic conditions prevailing in the preceding period and those of 2023 in particular.

The report by the Moroccan Meteorological Agency gives a clear account of the country's rainfall and temperature conditions. The year 2023 was the hottest since the beginning of the 20th century, with temperatures averaging 1.77 °C above the 1981-2010 baseline. It was also the driest for at least 80 years, showing a 48% rainfall deficit and marking the fifth consecutive year of drought in Morocco. Over the 2019-2023 period, the country as a whole recorded an 'extreme rainfall deficit' of around 35%, including a severe shortfall in precipitation (29.22% below normal), exacerbated by an exceptional rise in temperatures. As for the region we are concerned with, the province of Tata, conditions were even harsher, with a temperature increase of between 2.5 °C and 3 °C relative to the normal reference period, and annual rainfall between 50% and 80% below the same reference values. This led to between 30-40% greater evapotranspiration and a 30-50% water deficit **[30]** (pp. 12-13; pp. 26-28, Figure 26-27). However, these climatic conditions, clearly linked to global warming, had positive consequences for the images taken in May 2023. The extreme dryness and increased evapotranspiration accentuated the shadows created by moisture preserved at the bottom of the former irrigation channels, which rises to the surface by capillary action. In addition, the remains themselves generate shadows that are often visible – whether they rise above bare ground or, when buried by sand, produce minor topographical anomalies that reveal archaeological structures differently from agricultural structures. A further advantage of this aerial coverage for archaeological interpretation is that it already highlights the major agricultural transformations underway. Future satellite missions will reveal a landscape profoundly altered by new agricultural practices: in short, a terrain very different from the one we surveyed in 1999 during our fieldwork.

We extended our observations across a trapezoidal area of around 200 km², running parallel to the Jebel Bani and the isoclinal ridges of Izerzatene, bounded to the north-east by the *fūm* and the still-productive oasis of Aqqa, and to the south-west by a line located two kilometres downstream from the site identified as the abandoned medieval town of Tāmdult. It should be noted that the term

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fūm (in its original sense of 'mouth') is deeply ingrained in the toponymy of the Anti-Atlas because it refers to a geomorphological feature conducive to the exploitation of the aquifer. Specifically, it denotes the point where a wadi valley, deeply incised in the mountains, opens onto the plain; here, the configuration of the underlying geological strata creates a threshold that forces the aquifer to rise, producing resurgences **[31]**.

We then created a WebGIS interface on an IR Huma-Num* server. This phase of the work was carried out mainly by Laurent Costa (CNRS – UMR 7041 Archaeology and Sciences of Antiquity, ArScAn) and should form the subject of a dedicated publication at a later date. Into this interface we integrated the Airbus© image stream visible on Google Earth, dated 23 May 2023, together with the now historical IGN map, at a scale of 1/100,000 (Sheet NH-29-X-2, Akka – 1969), and the thematic maps derived from interpretations based on field observations and on the enlargement of a vertical aerial photograph from the 1952 IGN mission, which we had already used in 1999. Finally, we undertook a reinterpretation of the numerous fossil traces of archaeological remains, including buildings, irrigation canals, plots of land, and even the outlines and boundaries of cultivation plots).

4.2. Accomplishments of 1999-2011 and new results

The principal outcome of the 1999 fieldwork was the physical identification of a vanished ancient oasis – a 'first' in this field of Moroccan archaeology. An irrigated area, *or ḥawz*, linked to the foundation of the town, extended alongside it (Figures 2, 3 and 4). The hydraulic network that sustained it drew its source from the outlet *(fūm)* of Aqqa, carrying water across the plain to a point 2.3 km north-east of the town (Figures 2 and 4-A), beyond which began the irrigation of land organised into a field system extending a further 3 km south. The slope affecting the initial section was 0.53% (a drop of 81 m over a distance of 15.1 km), while the average gradient between the source and the downstream limit of the cultivated zone was 0.51% (91 m over 17.9 km). The total area under cultivation covered approximately 300 ha.

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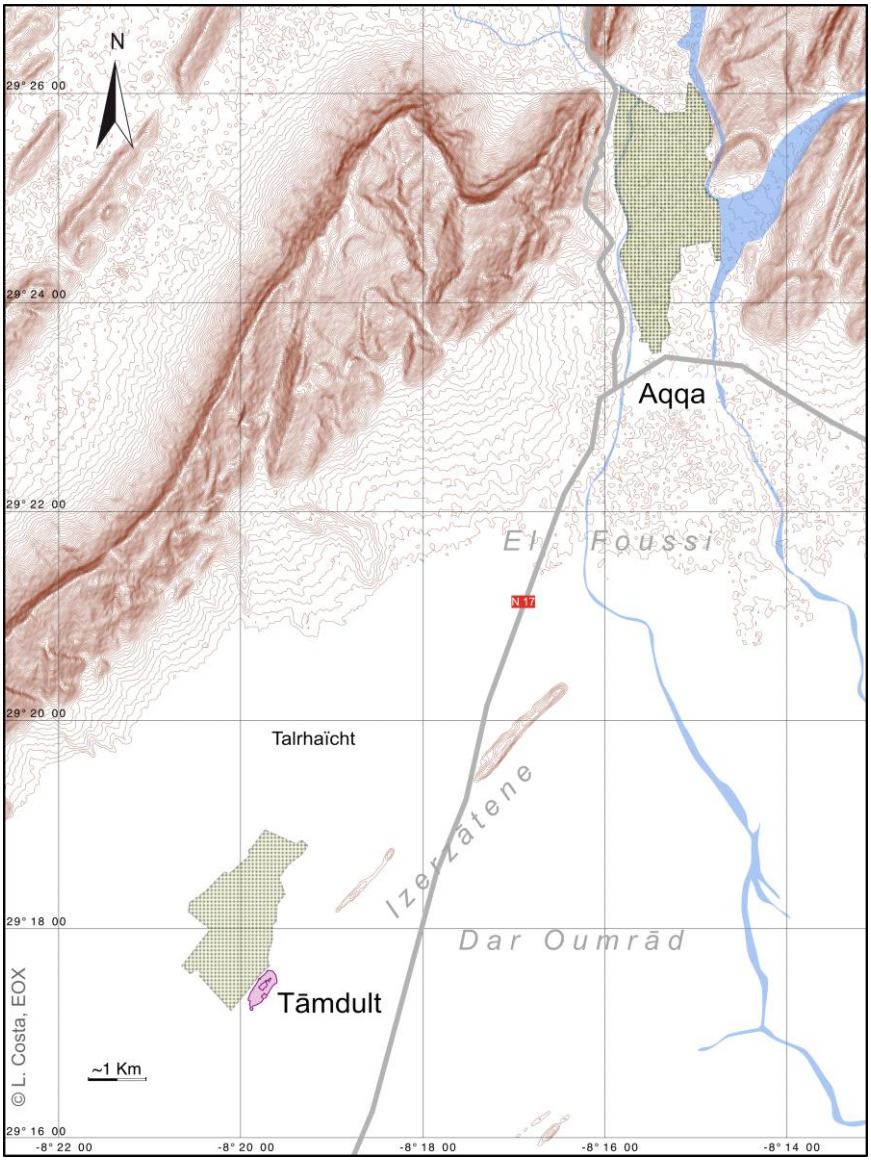

Figure 2. Respective locations of the oases of Aqqa and Tāmdult. © L. Costa, EOX.

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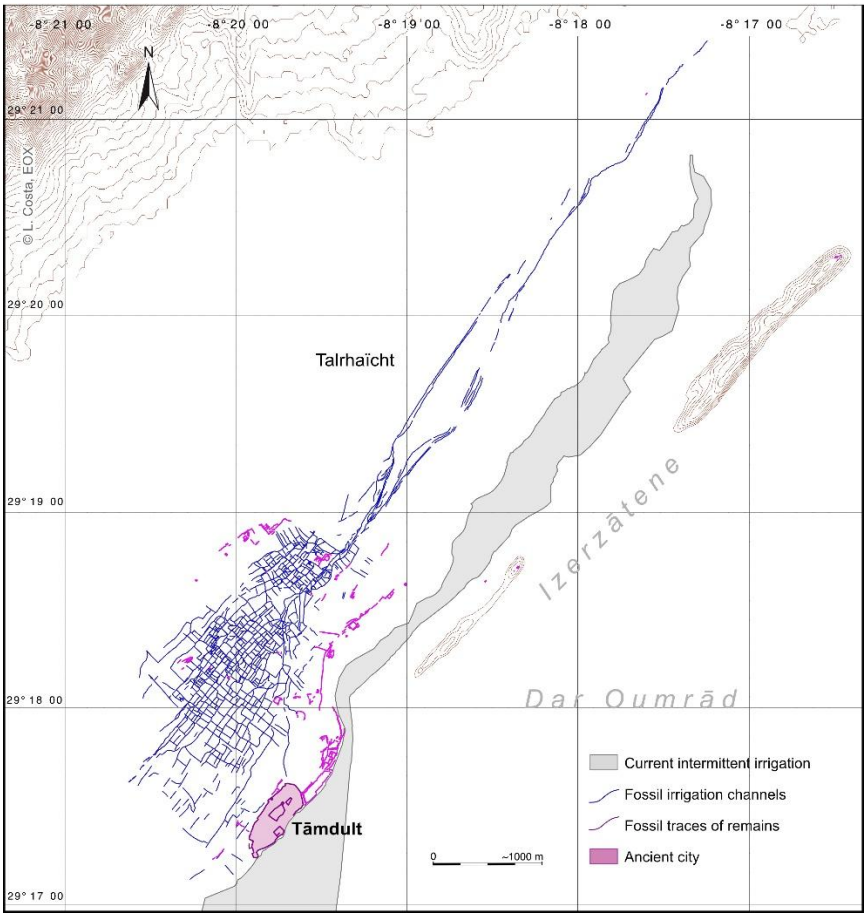

Figure 3. Tāmdult plain. Relative position of cultivated areas and urban settlements. © L. Costa, EOX.

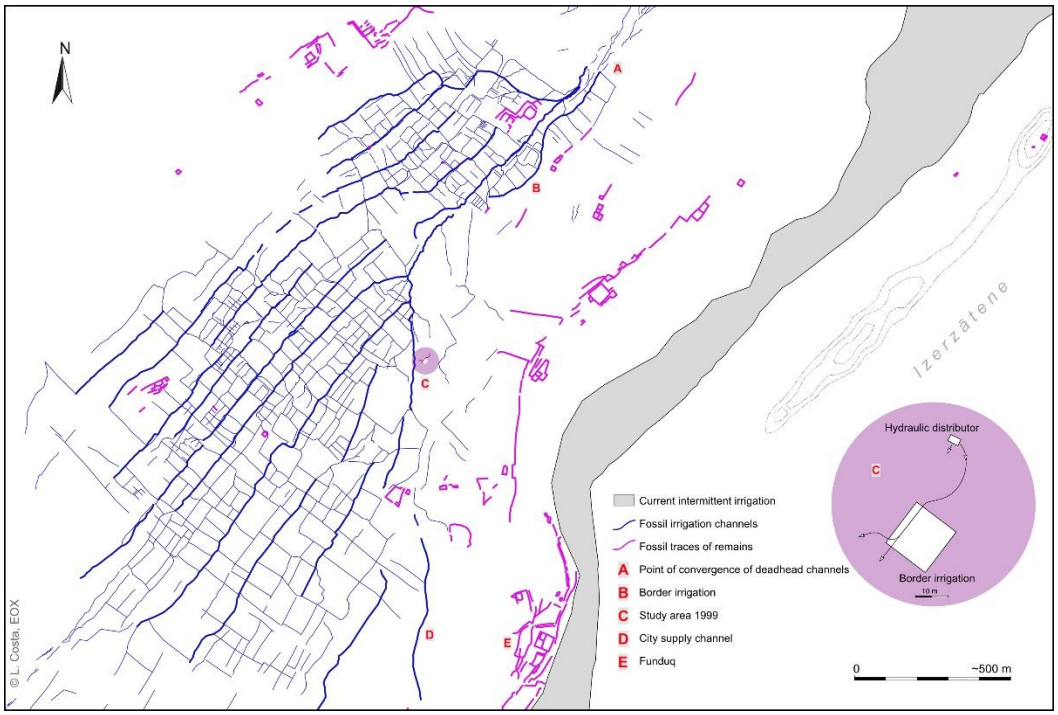

Figure 4. Tāmdult fossil Oasis. Hydraulic network, land plots and built remains. © L. Costa, EOX.

We were thus able to document the flood irrigation of cultivation plots and also to demonstrate the presence of an intercalated settlement within the field system, revealed by surface material: ceramic sherds (whose typology and morphology correspond to those of the assemblage recovered

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from our excavations in the urban zone), small hand millstones (for grinding grain or other domestic products), as well as large-diameter millstones indicating the existence of horizontal watermills installed along the irrigation canals (*sāqiya-s)* or on short branches derived from them. No associated regulating basin, however, was detected on the satellite images (Figure 7).

The origin of the water that irrigated the Tāmdult plain is suggested by the direction of the large canals visible in the images: the water intake was probably located between the ancient centres of the Aqqa oasis and the outlet of *the fūm*. The canals observed in the field were constructed in earth, raised about one metre above the surrounding ground (Figures 5 and 6). They flowed parallel to the Jebel Bani, at the foot of the erosional glacis overlooking the Tāmdult plain (Figure 3). Observation of this part of the network showed a system heavily fragmented by erosion. It was possible to identify at least four main canals, but no more than six. The routes ran parallel and were intended to supply water to the various sectors corresponding to the basic agricultural units defined by each of them.

Figure 5. "Dead head" canal upstream of the Tāmdult plain cut by modern works or river avenues. © RGV - Project *Genèse de la ville islamique.*

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Figure 6. "Dead head" canals upstream from the Tāmdult plain. Jebel Bani mountain range in the background. © RGV - Project *Genèse de la ville islamique.*

Figure 7. Hydraulic millstone on a canal diversion in the plain of Tāmdult. © RGV - Project *Genèse de la ville islamique.*

It should be emphasised that, although probably discontinuous at the level of each individual plot, the flow of the *sāqiya*-s was sufficiently constant to allow the proliferation of freshwater gastropods (observed in abundance along the canal routes), which could not have survived even brief periods of drought.

The abandonment of the irrigation system, after several centuries of operation, entailed the partial destruction of the layout of each technical unit of water distribution. Once the intake had lost its functionality, water circulation became limited to occasional torrential flows across the plain, caused by violent meteorological events and resulting in severe erosion of the canals. Evidence for

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this is seen particularly in their terminal sections, where several have been transformed into gullies or runoff channels. What can now be observed, both on the ground and through remote sensing, is thus a 'hybrid' system of surface water flow, both anthropogenic and natural. This explains the confusion of the cartographer who produced the IGN 1:100,000 map, the only official one available in 1999: the hydrographic network shown there indiscriminately mixes ancient *sāqiya*-s with natural or man-made ravines. Aerial imagery presents the same difficulty: it is often tricky to identify a canal, which is generally rather straight, that cuts across the 'meandering' dark traces formed by residual soil moisture.

Today, the Airbus© 2023 imagery allows us to confirm these observations in part. The multiplication of canals creates a palimpsest, not only (as we had previously thought) as a result of the degradation and hybridisation of surface water flow after the abandonment of agricultural activity, but also possibly due to dynamics inherent to the network during its operational phase. It is possible that the earthen *sāqiya*-s had already suffered damage while the oasis was still active, and that partial or alternate reconstructions were responsible for the multiplication of traces visible on the Airbus© 2023 mission imagery. It should be remembered that in 1999 we had identified the dead heads (the sections of the conduits between the intake and the first point of water use) of between four and six main canals, extending from the *fūm* downstream for up to 15 km. In certain places, the parallel alignments of two canals were separated by a very small distance – barely 4 to 5 metres (Figure 6).

The open-air flow of water combined with the high temperatures of the region led to the formation of dense calcareous concretions at least 30 cm thick, coating the inner walls of the canals and in some places reducing their functional cross-section to a width of about 60 cm at the end of the hydraulic system's active life.

Today, despite the quality of the 2023 satellite imagery, we cannot yet assess with any certainty the exact number of canals upstream of the cultivated fields. Even though the traces appear to multiply, the indicators interpretable as water conduits cluster around four major 'flows'. Here, we apply to our analysis the conceptual framework proposed by S. Robert **[32]** (pp. 95-101, Figure 3-18, 3-19) for the study of road networks. That author suggests interpreting such systems by distinguishing three analytical levels: the *flow, the route,* and *the construction.* The first, the flow, represents the relationship established between two poles involving movement or transport. In our case, this is the transport of water between the intake and the irrigated plots. The second, the route, is the optimum path determined by topographic conditions, allowing for measured flow and efficient distribution; it results from empirical calculations made by the builders. Finally, the construction refers to the mode of viability, the main or secondary route, that is to say, in our case, the hierarchical level of the canal within the system: primary, secondary, or tertiary. In the upstream section of the network, the impression is one of multiple routes organised around four major flows carrying water from the intake at the level of the *fūm* of Aqqa. This multiplicity could also be interpreted as alternative configurations of a still-functioning system, later supplemented and altered spontaneously after its abandonment by torrential and destructive watercourses generated by climatic events. In addition, certain 'inconsistencies' in the fossil traces (Figure 3) may suggest the existence of other flows originating from short ravines on the Jebel Bani, oriented differently from that of the oasis's hydraulic network. The hydrological and geomorphological characteristics of these short valleys indicate that such flows could only have been episodic and violent, yet no traces of possible diversion dams intended to incorporate this water into the system, (as are known, for example, in the Algerian Mzab **[33] (**pp. 169-175), could be identified on the ground or in satellite imagery.

However, the principal new insight provided by the 2023 Airbus© image concerns the area where the canals cease to be mere 'dead heads' (initial segments whose sole function was the conveyance of water) and where the first cultivated fields appear. In 1999, lacking higher-quality imagery and with no readable remains visible on the ground, we had interpreted the original labour investment required to construct four or six separate flows, instead of a single channel – an apparently

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disproportionate undertaking – as the solution adopted by the founding communities of Tāmdult in order to preserve their autonomy in the management of water and land. Logically, this plurality of flows ought to have continued downstream, with the parallel circulation of the different channels feeding the strips of land [3] (Figure 3, canals 1-4). Yet the photo-interpretation of the 2023 image appears to suggest a certain convergence towards a zone located 15 km from *the fūm* and 2.3 km north-east of the outer perimeter of the ruined settlement identified as the medieval town (Figure 4-A). Here, the four to six major flows lie less than 40 m apart. It is from this small area, where the various routes unfortunately become blurred on the satellite image, that a clear branching dispersion occurs, spreading out from each *sāqiya*. However, this convergence cannot be interpreted as a merger of the flows into a single canal. Indeed, remote sensing cannot determine the chronological sequence of the network's development, nor confirm or refute the contemporaneity of the large, almost rectilinear canals. The junction of the dead heads would have required the construction of a substantial hydraulic infrastructure, a large accumulation and redistribution basin. It is therefore difficult not to question the value of such a costly arrangement: the multiplication of canals upstream would have entailed a significant additional expense in the construction and maintenance – a total of 60 km (15 km for each of the four canals) or even 90 km (if six) – only to bring the waters back together halfway downstream. One possible explanation for this apparent incongruity is the need for multiple intakes along the wadi to maximise the exploitation of available water resources, which does not exclude the distribution of land and water by lineage within a single (tribal) population group, since it appears that the major *sāqiya*-s remain autonomous beyond the convergence zone.

In 1999, drawing on the few remains clearly visible in the aerial photograph, we were able to define the field morphology generated by the hydraulic system. It consisted of a series of 'bands with a regular orientation (NG-38.8°E) whose intermediate boundaries – the major *sāqiya*-s – run longitudinally across the plain for 3 km, while their secondary canals intersect the bands transversely'. The six bands thus identified can be related to the maximum number of four to six major flows proposed above. They extend with a constant orientation (though with very slight variations between the upstream and downstream sections) over 2.9 km, between the point of confluence of the dead heads and the end of the irrigation network. These bands display signs of metrical regularity, although it remains difficult to quantify: the central band has a module of approximately 75 m in width between the axes of the *sāqiya*-s, while elsewhere values close to 84 m are observed. The only exception to this general orientation of the system is a very distinct canal, visible for a distance of 1.5 km on the 2023 imagery, which in 1999 had been interpreted as a palaeo-channel. This canal runs towards the northernmost part of the town of Tāmdult and passes close to a 2,400 m² building (Figures 3 and 4-D).

Within the areas delineated by the canals themselves (1999 study area, Figure 4), it is possible to reconstruct the irrigation system using dividers that distributed water from the higher-order canals to the secondary and then tertiary ones, and so on down to the level of the individual plot (Figures 8 and 9). These figures show the long duration of use of these structures, with several phases of operation and the presence of layers of aquatic gastropods (Figure 9). They also illustrate the layout of cultivation plots within each parcel, a typical organisation of oasis systems, as was still practised in the Aqqa oasis at the time of our field surveys and the brief ethnographic study we conducted there (Figure 12). This irrigation technique is particularly suited to low-gradient soils, with slopes between 0.2% and at most 3%, allowing the flooding of the area bounded by small earthen ridges or bunds, shaped with a hoe, about 20 to 30 cm above the water level. The method is mainly used for growing cereals, alfalfa, and vegetables **[34]** (pp. 2-3) **[35]** (pp. 29-32). These crops form the lower stratum of the three that constitute oasis agriculture: 1: date palms; 2: fruit trees; and 3: cereals, market-garden species, and fodder plants **[36]** (p. 312).

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Figure 8. Hydraulic diverter in the study field area (1999). © RGV - Project *Genèse de la ville islamique.*

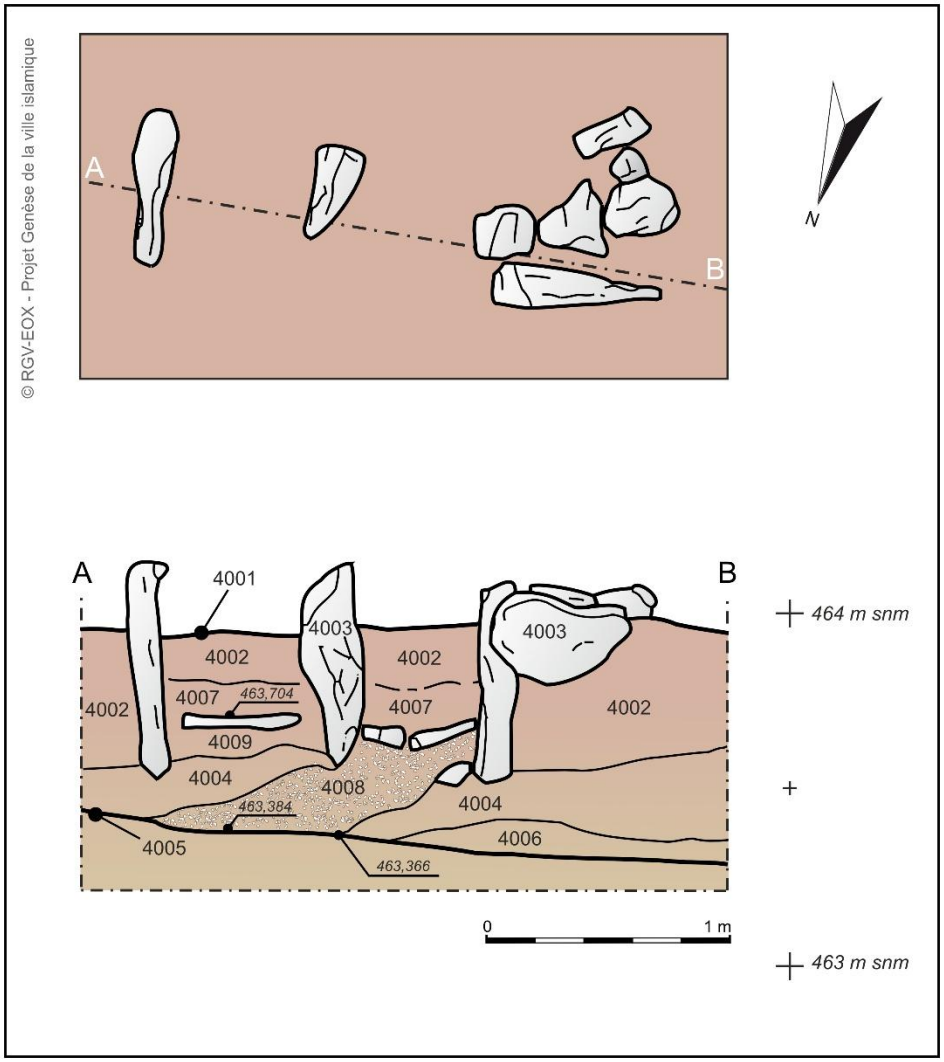

Figure 9. Plan and section of a hydraulic diverter excavated in the study field area (1999). © RGV-EOX - Project *Genèse de la ville islamique.*

In 1999, through excavation within the fossil field system, we were able to document several of these micro-agricultural structures, a level smaller than the parcels themselves, by conducting a

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detailed ground analysis of a 225 m² test window (Figures 10-11 and 13). The excellent conditions at the time the Airbus© satellite images were taken, combined with their high resolution, now make it possible to extend this analysis to the scale of the entire *ḥawz* (Figure 14). The cultivation plots are grouped within 'cultivation quarters' (equivalent to urban blocks), defined by secondary *sāqiya*-s. These quarters may contain several parcels, but it is not always easy to discern any subdivisions beyond those of the plots themselves. The plots are roughly rectangular, bounded in turn by small earthen ridges, and their longer side generally runs parallel to the path of the water. Their size varies, no doubt adapted to the type of crop grown, the season, and the preferences of each farmer, ranging from 12 to 60 m² (around 250 to 1,000 square feet), with an average of 23 m² (around 580 square feet) (close to the 21 m² (around 570 square feet) of the only complete example excavated in our observation window in 1999 (Figure 13).

Figure 10. Secondary channel partially excavated in the 1999 study field area. Jebel Bani mountain range in the background. © RGV - Project *Genèse de la ville islamique.*

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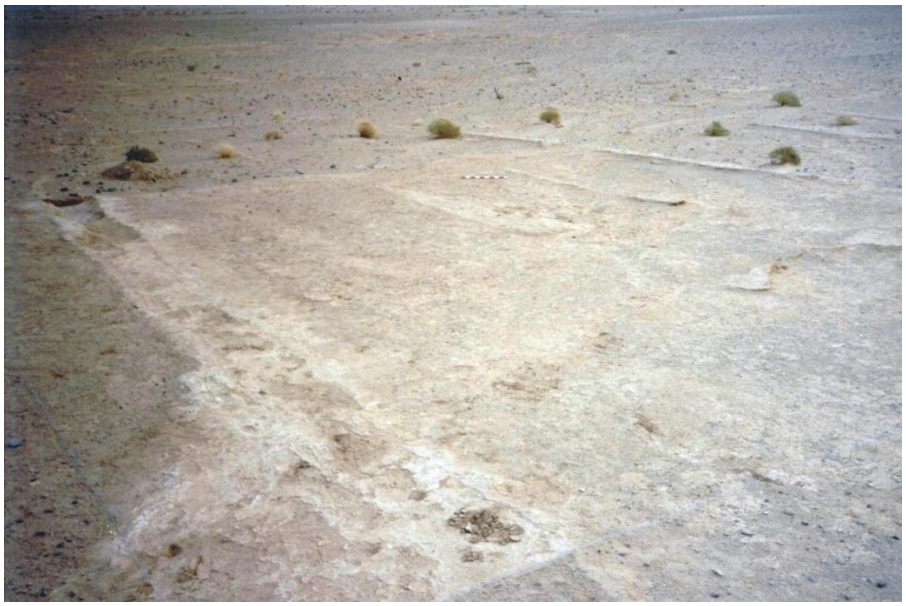

Figure 11. Secondary channel excavated and border irrigation system in the study field area (1999). © RGV - Project *Genèse de la ville islamique.*

Figure 12. Border irrigation system observed in 1999 in the Aqqa oasis. © RGV-EOX - Project *Genèse de la ville islamique.*

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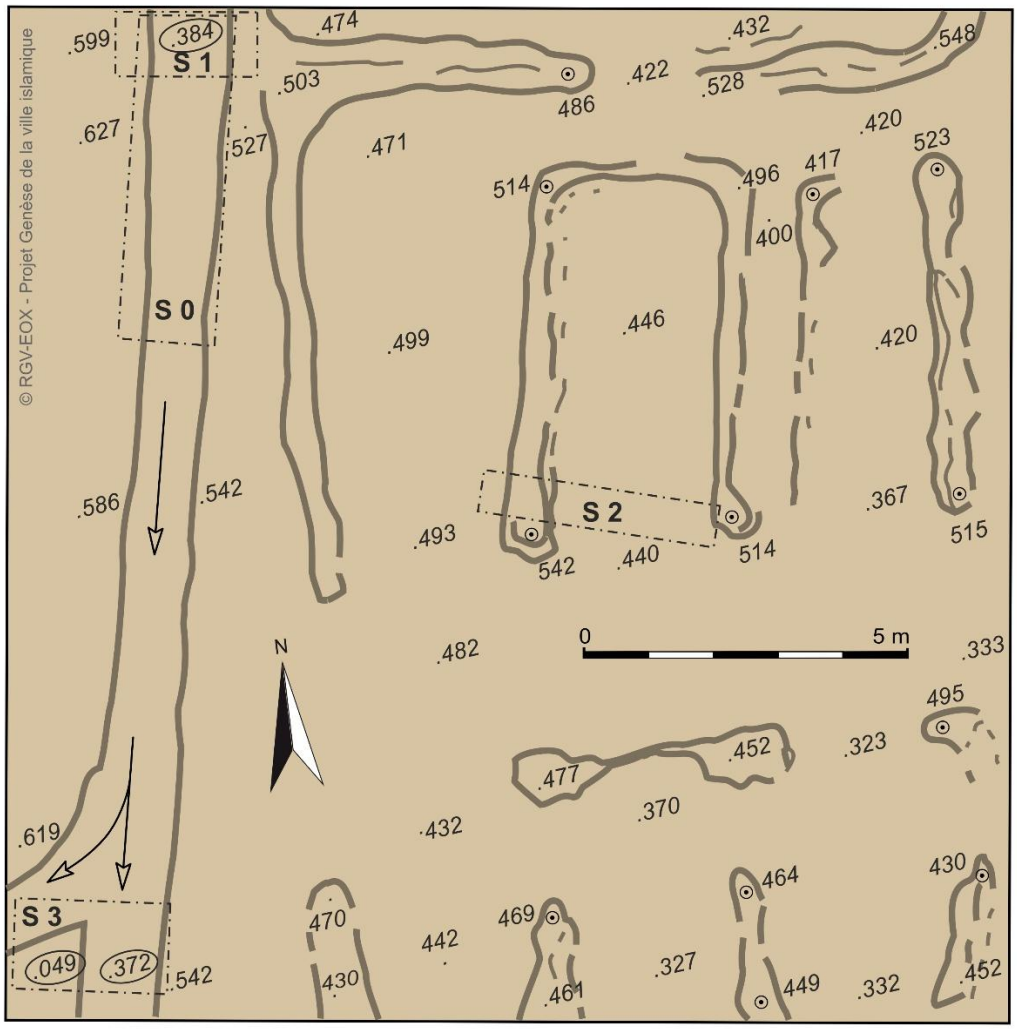

Figure 13. Partial plan of border irrigation stripped in the study field area (1999). © RGV - Project *Genèse de la ville islamique*.

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Figure 14. Border irrigation in the Tāmdult plain visible in the 2023 ©Airbus mission (see Figure 4-B, 11).

This oasis landscape included buildings occupying the interstitial spaces between canals and cultivated fields. The aerial photographs used in 1999 already showed a large number of these structures, often located on ground slightly higher than the fields, but they appear much more clearly and in greater numbers on the Airbus© 2023 imagery. Following surface surveys, we interpreted these structures as habitation sites (attested by the presence of potsherds and hand-mills), whose main activities were both agricultural (proximity to *sāqiya*-s and cultivation plots) and craft-based (evidence of metallurgy, such as slag stains). Although the mapping of these structures can – and must – still be refined, remote sensing does not allow for a more detailed characterisation of the buildings. However, it is worth noting that some of these mounds are identified by local inhabitants as *burǧ*-s ('towers').

Among the buried archaeological structures that we were able to identify, particular attention should be drawn to those on the periphery of the ancient town. At its north-eastern extremity, alignments and complex buildings can be discerned, linked by what appear to be long passages between two parallel walls. Their extramural location, their overall dimensions (between 7 and 10 ha), and the presence within this area of a square building measuring some 2,800 m², suggest that this was a *funduq*-type complex, a conclusion consistent with Tāmdult's role as a commercial hub situated at the crossroads of caravan routes (Figures 3 and 4-E).

An obvious question arises: how much land, and how much water, are we talking about? In light of the preceding discussion, we deemed it relevant to estimate (at least approximately) the volume of water required to meet the needs of the palm groves of Tāmdult and Aqqa, and, hypothetically, those of the two oases if they had operated simultaneously. Fully aware of the uncertainties inherent in this type of calculation, we nevertheless consider it useful for assessing, on the one hand, the effort undertaken by the builders of the Tāmdult oasis to conduct water from the *fūm* to the plain; and, on the other, for defining the operational limits of the two oases functioning separately or jointly with the flow currently available at the *fūm* of Aqqa. It should be remembered that no archaeological evidence has yet demonstrated the contemporaneity of the present-day oasis of Aqqa and the now-abandoned one of Tāmdult. The parameters for this calculation derive from Kh. Amrani's estimates of water requirements, following other authors **[37]** (pp. 93-95) **[38]** (pp. 209-210), summarised here in a table (Table 1). To this end, we also used the flow and abstraction figures for the basin and the *fūm* of Aqqa provided by the Draa Oued Noun Water Basin Agency. These are 600 L/s for the total flow and 200 L/s for water abstraction **[39].** Nevertheless, these figures must be interpreted with caution. The reference standard used by Kh. Amrani is 20,000 m³/ha/year for a density of 100 palm trees per hectare, though the author also notes other reference values that vary primarily with palm-tree density. G. Toutain **[40]**, moreover, highlights an apparent paradox: that a higher density of palms actually reduces total water requirements by providing more shade for crops in the lower strata and consequently reducing evapotranspiration. If we assume a withdrawal of 200 L/s at the *fūm* of Aqqa, and irrigable areas of 600 ha for the Aqqa territory and 300 ha for that of medieval Tāmdult, we immediately observe that, in most hypothetical estimates, the required volume exceeds that allowed by the current discharge. Even though the Aqqa oasis remains functional today, this is only possible through the overexploitation of the aquifer. Numerous studies on Saharan and pre-Saharan oases show that such overexploitation is now widespread, while traditional irrigation causes losses estimated at 30% through evapotranspiration or percolation **[41]** (p. 6). The most important point revealed by these data is that it is very difficult to imagine both oases functioning simultaneously, unless one were to adopt much more optimistic assumptions regarding their water requirements.

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Table 1. Estimated flow required to meet the water needs of the Aqqa and Tāmdult oases according to various authors cited by Amrani **[37]** (pp. 93-95), **[38]** (pp. 209-210).

Author.	Palm tree /ha	m^3/ha/an	Tāmdult l/s	Aqqa l/s	Tāmdult + Aqqa l/s
Toutain (1979)	156	6910	66	142	208
Toutain (1979)	120	10489	100	216	316
Toutain (1979)	100	12340	117	254	372
Langronier (1935)	130	17940	171	370	540
Amrani (2021)	100	20000	190	412	602
Foaden & Fletcher (1959)	129	22075	210	455	665
Jus (1900)	130	22750	216	469	685
Monciero (1950)	130	26383	251	544	795
Gauthier (1935)	130	33927	323	699	1022
Rannou (1935)	130	38700	368	798	1166

If we assume that both oases functioned simultaneously, two scenarios are possible. The first is that this occurred for a limited period, under hydrological conditions similar to those of today, but only until overexploitation of the aquifer rendered it unsustainable. The second would imply more favourable hydrological conditions at the time of the foundation of one or both systems, followed later by climatic deterioration that eventually forced the abandonment of one of the territories, at a date yet to be determined.

5. The Difficult Question of the Timing and Agents of the Planning of Peri-Urban Irrigated Areas in Oasis Environments: Tāmdult vs Aqqa

After this renewed overview of the morphological characteristics of Tāmdult's hydraulic network and of the field system it sustained over several centuries, we must return to two essential questions concerning it: first, that of its chronology (including whether or not it was contemporary with the nearby oasis of Aqqa, situated 15 km upstream); and, second, that of the identity of its builders.

Let us first note that archaeological excavations – both those conducted at the site so far identified as medieval Tāmdult and those carried out within one of the 'ancient' nuclei of Aqqa (around the mosque known as Agadir Amġār), have yet to provide any decisive answers. So far as we know, neither has yielded ceramic or numismatic material that can be identified with certainty as Idrisid-period. As for the aforementioned mosque, once considered by some to be Almoravid, it is now dated to the Saadian period **[42]**.

From the sole perspective of the logic of water-resource exploitation, it would have been more plausible for the earliest settlement to have been located at the very outlet of the *fūm*, where the water naturally emerged – a location that would moreover have spared the time-consuming and labour-intensive task of building a network of canals stretching over 10 km. The foothill relief would also have allowed for the establishment of defensive structures essential to any urban settlement.

If the prior existence of the Aqqa site were to be confirmed, the expansion of the oasis could only have taken place downstream, where there were potentially cultivable lands suitable for irrigated agriculture – and where diversion intakes from the wadi would not encroach upon the water rights of already established communities, since it was the resurgences of the aquifer in the wadi bed downstream of the original field system that would then have been exploited.

Conversely, if the site so far identified as Tāmdult were indeed the Idrisid foundation, and the Aqqa oasis represented a later upstream extension, it is clear that the latter would have appropriated the water resources of the former, thereby bringing about its decline and eventual ruin. This second scenario is theoretically plausible and would apparently explain the migration of populations at the end of the Middle Ages, as recounted by oral tradition that attributes it to unspecified intertribal

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conflicts. However, it runs up against the irrationality of an original settlement that would have required such heavy infrastructure, when the upstream natural site was far more favourable.

A third scenario can also be envisaged, that of simultaneous or near-contemporary foundations, resulting in a dual urban centre, as occurred elsewhere in the early Islamic Middle Ages, particularly in the Idrisid Maġrib al-Aqṣā (such as Fez or Aġmāt) [**25**]. Yet one must wonder why the medieval sources did not consider it worthwhile to note this peculiarity. What is certain, in any case, is that the two settlements coexisted (already, or still) in the 12th-13th centuries, as shown by ^{14}C (radiocarbon) dates from Agadir Amġār [**42**], along with the coins and ceramic assemblages recovered during our excavations at Tāmdult.

It is possible to envisage the foundation of one and/or the other during the Idrisid period, under the patronage of ʻAbd Allāh ibn Idrīs ibn Idrīs or ʻUbayd Allāh ibn Idrīs. Yet it should be remembered that in none of the urban foundations of this period in the Maghreb was the decision to initiate the urbanisation process made by the dynast alone. The local tribal fabric was always directly involved, both in the decision-making and in the implementation [**25**]. However, the precise identity of the tribes of the Aqqa region in the 9th-10th centuries remains unknown. Only al-Yaʻqūbī refers to them, in generic terms, describing Tāmdult as a town of the Banū Tarğa, whose population was a mixture of Berbers, mainly Madāsa [4**]**. The Banū Tarğa, moreover, constituted a vast ethno-cultural group of the Sahara fringe – later one of the major components of the Almoravid movement – and must have been subdivided into smaller groups, including all or part of those who inhabited the Jebel Bani and its foothills at the time of the arrival of Islam.

The study we carried out on the town of Aġmāt [26,43], probably founded at the same time as Tāmdult, but located north of the High Atlas, showed that the system for capturing and distributing irrigation water intended for the development of a peri-urban territory differed in no way from those documented in strictly rural areas, including in other geographical regions of the country. The internal hierarchy of the hydraulic network was therefore established – at least originally – in the image of the segmentary structure of tribal society. As noted above, this feature remains a convincing explanation for the existence of the four or six major *sāqiya*-s, whose dead heads run parallel for several kilometres before taking convergent directions (though seemingly without ever mixing their waters), and then maintaining autonomous distribution within the field system. Two other, non-exclusive explanations, unrelated to the social organisation of the time, can also be proposed: the staggered positioning of several intakes along the wadi, depending on their spontaneous resurgences; or the need to restore the system after destruction, whether natural or conflict-related, which may have required new sections.

Of course, more broadly speaking, there remains the unresolved question of the hydraulic knowledge and technological background of the pre-Idrisid tribes of the pre-Saharan Anti-Atlas. In the present case, however, it was above all topographical expertise that was essential. The modesty of the intake structures, simple and fragile diversions along the course of the Aqqa wadi, necessarily required periodic repairs, which could readily have been carried out within the framework of collective labour, as is still almost invariably the case in Maghrebi peasant communities today. In this respect, the dual process of urbanisation and construction of a hydraulic infrastructure enabling the revitalisation of an extensive territory, as we have documented at Tāmdult, differs significantly from what has been observed at Siğilmāssa at virtually the same time or only slightly earlier. Indeed, the scale of the works in that other major caravan hub (including the excavation of an artificial wadi bed and the installation of a retention dam to regulate flash floods) clearly suggests decisive intervention of political authority, or even the participation of specialists from the East, familiar with the kind of large-scale hydraulic engineering practised there [**28**].

It is well known that from the late Middle Ages in Morocco, the great religious brotherhoods played an important role in the development of irrigated agriculture [**44**]. Yet it is inconceivable that the rise of the *zāwiya* of Aqqa, from the early 16th century onward and especially under the Saadian Sultanate, could have had any impact on the layout of the hydraulic network belonging to a settlement already abandoned for several decades. However, the descendants of *šayḫ* Sīdī

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Muḥammad ibn Mbārk probably played a role in the management of the upstream oasis system, as well as in the allocation of its associated habitation, such as Agadir Ūzru, by ‘Abd Allāh ibn Muḥammad ibn Mbārk in 1563.

If there is a ‘discrepancy’ between the original layout of the Tāmdult hydraulic system and the configuration derived from our field observations and satellite imagery, it is primarily the result of the long period of abandonment and erosion that followed the ruin of the town, the emigration of a large part of its population, and the withdrawal of the remaining inhabitants towards Aqqa.

In conclusion: definitive answers soon?

In conclusion, it is worth noting some similarities and differences between the morphology of the two oases, Tāmdult and Aqqa. By virtue of its very position at the precise outlet of the *fūm*, a genuine rocky lock that causes the resurgence of the wadi, the hydraulic network of Aqqa does not include long dead heads but is immediately functional. The organic morphology of its canals and plots appears less regular than that of Tāmdult. The distribution of habitation occurs, as in the downstream settlement, around the periphery of the irrigated territory, but in multiple autonomous nuclei, probably reflecting a longer diachronic development, as attested, without taking into account the modern administrative centre, by the founding of Agadir Ūzru in 1563 by the *šayḫ* of the *zāwiya,* ‘Abd Allāh ibn Muḥammad ibn Mbārk.

The archaeological research conducted on the fossil oasis of Tāmdult has revealed a clearly planned structure, apparently more regular (though it has not been possible to determine its precise module). The joint establishment of the hydraulic network and the field system must have required a tremendous human investment, since it involved both bringing water essential to the creation of these agricultural spaces and building a town that was, paradoxically, located at some distance from its water resources.

The scale of this investment presupposes the intervention of a powerful authority, whether that of a nascent ‘state’ (as such could be conceived in the early Middle Ages, and as it is often tempting to hypothesise) or that of a coalition of tribes pooling their resources. The economic potential of the Tāmdult region was considerable, as was recognised early on (its silver and copper mining resources are mentioned frequently in textual sources). Labour could have been mobilised through collective corvee, customary in Amazigh society, but perhaps also through slavery, though we lack information on this practice in Saharan regions during this early period.

In Tāmdult, the fate of the town and that of the oasis were linked: their lifespans could only coincide. Such interdependence is not always advantageous when it breaks down. As G. Chouquer points out: ‘Synchrony or disruption of form over time occurs when social intervention in the environment creates a new state consistent with the social formation in question; most planning falls within this category’ **[45]** (p. 125).

The two oases functioned synchronously, at least for a time – perhaps from the beginning – and, as we have seen, they could not have endured with water resources equivalent to those available today. One must therefore conclude that water availability was greater in the past. A hydric crisis, whether caused by natural factors or by the destruction of hydraulic networks during regional conflicts, must have occurred at the end of the 15th or early 16th century. The crisis, generating social and economic tensions, likely coincided with a possible slowdown in trans-Saharan trade, despite the efforts quickly made by the Saadians, who fortified and restored the region’s routes, extending their control as far as the southern edge of the desert. This could also correspond to the peak of drought detected by dendrochronology during the first third of the 16th century in southern Morocco **[46]**.

We have here only laid the groundwork for resolving a series of questions concerning the absolute and relative chronologies of the Aqqa and Tāmdult oases, as well as the identity of the builders of the hydraulic systems observed. The hypotheses put forward stem from a reading of the written sources, from field observations – carried out under the difficult material conditions of a quarter of a century ago – and from the analysis of aerial and satellite images. Several ongoing projects should now take up the task, confirming or refuting our conclusions, and providing more

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precise answers – whether by dating the earliest occupations of the two oases, downstream and upstream (*The Djbel Bani Archaeology Project)* [23,24], or by supplying new data on the possible practice of irrigated agriculture prior to the arrival of Islam in southern Morocco (*The Middle Draa Project)* **[47]**. These pages, in any case, bear witness to our hopes and efforts.

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