GeoScience Engineering

EVOLUTION OF TRADITIONAL WATER COLLECTION TECHNIQUES IN THE ALGERIAN SAHARA

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ABSTRACT

This article discusses many of the inherited techniques for collecting and managing spring water used in the gardens of Boussaada, Ain Madhi, Small Mechria, and Stitten located in the Saharan atlas' ranges over a period of nine centuries. Based on the missions carried out since 2017 in the four regions, we conducted site investigations and surveys of the local population. The results showed that domestic water supply and irrigation were carried out using traditional water collecting techniques such as well and foggara and small dams. The water harvesting technology characterizes a specific region according to its topography and hydrology. Currently, this hydraulic heritage meets technical and social problems, especially with the advent of modern technologies that give more water with less human effort but hurt the environment. The objective of this study is to conduct a comprehensive inventory of all water sources in the study areas while evaluating the negative impact on them due to the emergence of modern technologies.

Keywords: Algeria; Dam; Foggara, Oasis; Source; Valley.

1 INTRODUCTION

The Saharan Atlas is characterized by an arid climate where the average annual rainfall does not exceed 100 mm. However, considerable amounts of water are stored underground for subsequent extraction from aquifers. In the region of Tiout, the oases stored the spring waters by the Source Dam [1]. In the Moghrar region, the oasis people catch water through the foggara system [2]. In the Lahmar oasis located on the outskirts of the city of Bechar, the oasis people have made two types of Foggaras: Mountain Foggara, and Spring Foggara [3]. The regions of Boussaada, Ain Madhi, Stitten and Small Mechria located on the chains of the Saharan Atlas are characterized by a multitude of their sources of water. According to a region's geological, hydrogeological, and topographical conditions, each area allows us to discover its advantages in water management. In this article, we study the multiple ancestral techniques for capturing spring water in the regions (Boussaada, Ain Madhi, Small Mechria, and Stitten) which are in the middle of the Saharan Atlas. The multiplicities of the modes of exploitation of this traditional system will be the subject of this study, as well as the causes of deterioration of these systems.

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2 STUDY AREA AND DATA USED

2.1 The geographical location of the study region

The Saharan Atlas extends from the Moroccan Highlands to Biskra in the east. It is formed by a set of mountains (Ksours, Djebel Amour, and Ouled Nail). Boussaada, Aïn Madhi, Small Mechria, and Stitten, the hyper-arid region is located at the Saharan Atlas ranges (Figure 1).

Belonging to the Wilaya of El Bayadh, the region of Small Mechria is located 670 km south-west of Algiers. The region of Stitten is located at 635 km south-west of Algiers. On the other hand, the oasis of Boussaada is located 270 km south-east of Algiers, and the region of Aïn Madhi is located 476 km south of Algiers.

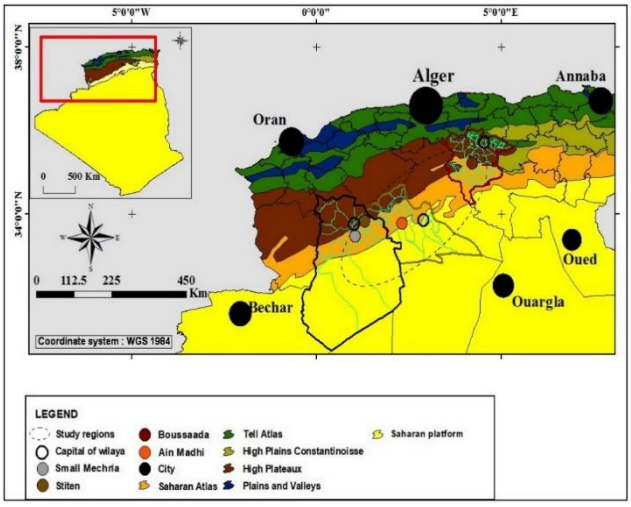

Figure 1. *The geographic location of the study regions (modified according to [4])*

2.2 Characteristics of the study area

The four regions are part of the Saharan Atlas Mountains, characterized by the existence of several water sources that are located on the banks of the "Wadi" (Valley). The availability of water in the region has enabled farmers to develop new land and expand the palm grove.

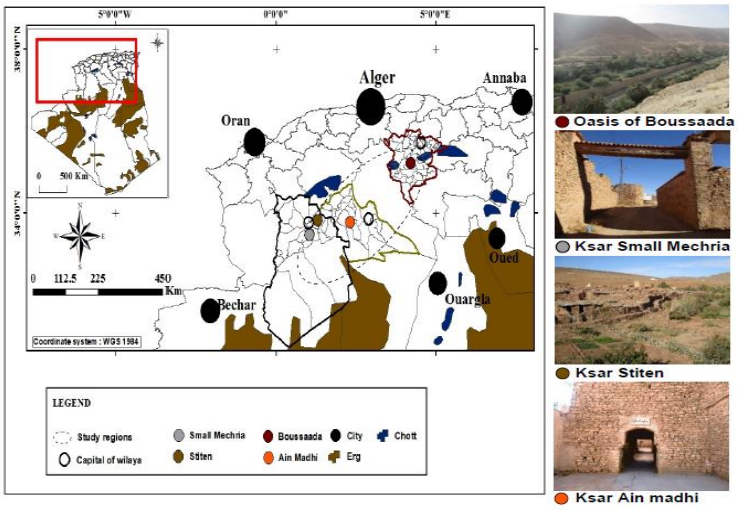

Figure 2. *The geographic location of the study regions (modified according to [5])*

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3 RESULTS AND DISCUSSION

3.1 Source dam

On a 2-km stretch of Wadi Boussaada within the 102,000 ha sub-watershed located southwest of the Honda watershed (Figure 3), a series of cascading dams are centred there (Figures 4–6). Unlike the Ouakda oasis dams fed by runoff water [6], the Boussaada dams are continuously fed from water sources to irrigate the valley's oases continuously. These dams sometimes become a sight for visitors.

3.1.1 The originality of the oasis of Boussaada

Contrary to the oases of Touat and Gourara which are supplied with water by the system of foggaras (Figure 7), and in accordance with the oasis of Tiout (Figure 8), Boussaada is supplied with water by a system of cascading dams. The originality of this hydroelectric-based oasis has remained in the function, which is intended to generate electric power to power the grain mill.

3.1.2 The palm grove of Boussaada

The palm grove of Boussaada with a total area of 155 ha (Figure 9) is intended for the self-reliance of the local population. In addition to 6,000 date palms [7], various types of fruits and vegetables are grown in the gardens (Figure 10). The irrigation of the gardens was carried out by the waters of the two dams through two main "seguias" (channels) called Seguia Khachbat and Seguia Nakhara (Figure 11).

3.1.3 Spring water

The local populations rely on spring water to satisfy the drinking water supply of the ksar and the irrigation of the palm grove located on the bed and banks of the "wadi" (Valley).

We counted three types of sources of springs discovered in Boussaada:

- The spring water is located on the left bank of the valley coming from the phreatic zone, which is recharged by the infiltration and drainage of irrigation water (Figure 13).
- The spring water is located on the left bank of the valley coming from the phreatic zone, which is recharged by the infiltration and drainage of irrigation water (Figure 14).
- Springs along the beds which recharges from runoff from "wadi" (valley) water (Figure 15).

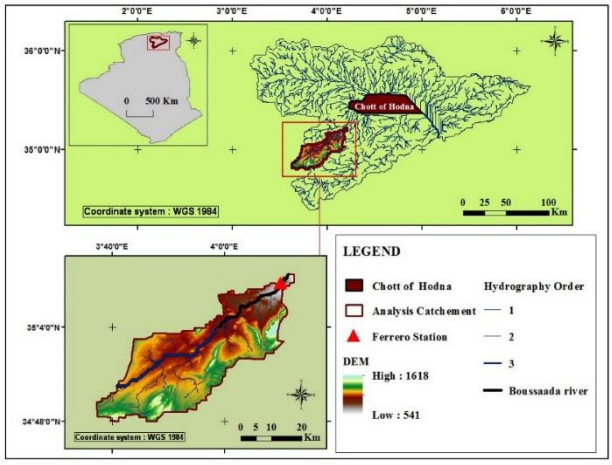

Figure 3. "*Wadi"(Valley) Boussaada sub-watershed (made using SRTM data)*

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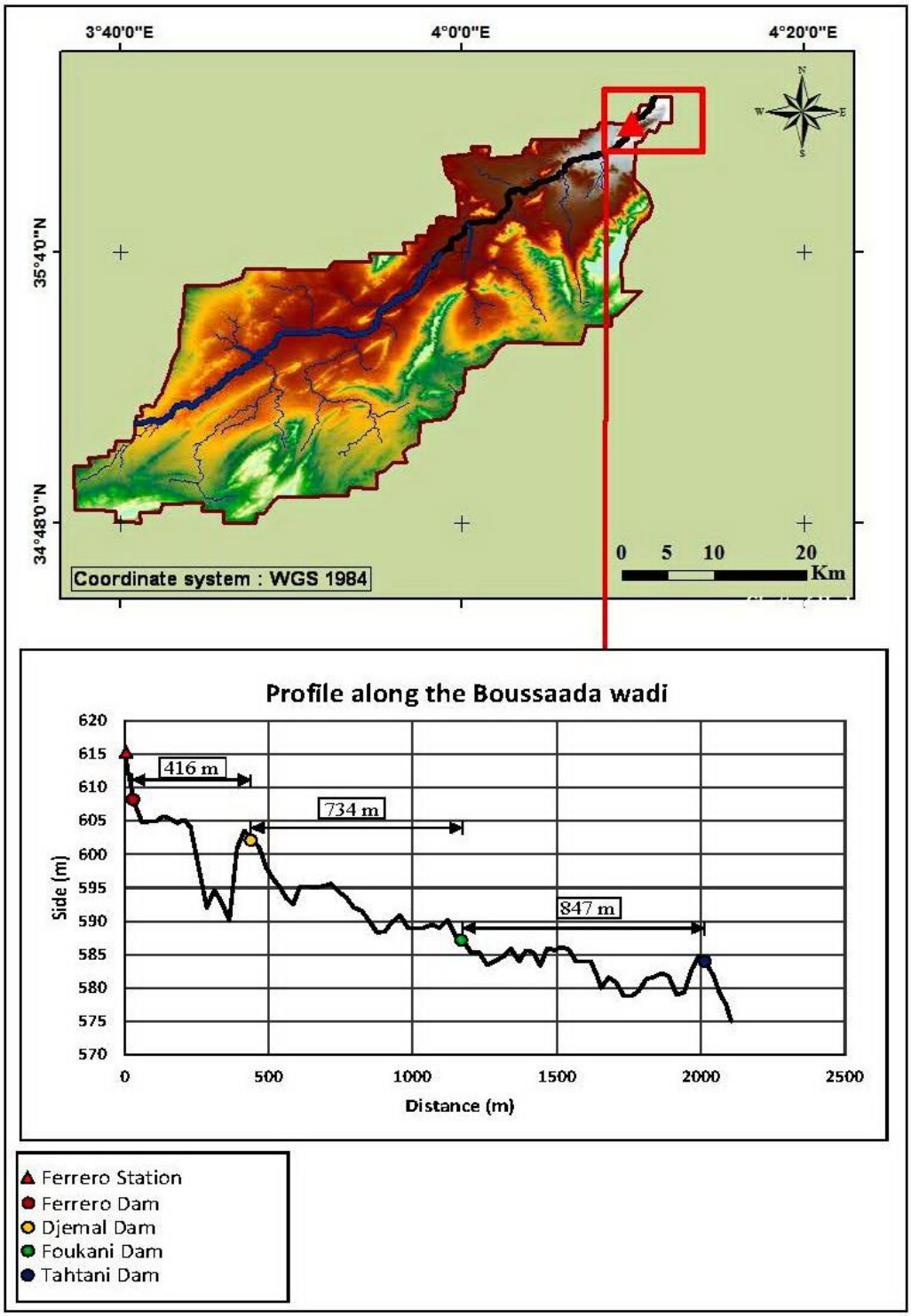

Figure 4. *The section of Boussaada "wadi"(Valley) on which the dams was built (made using SRTM data)*

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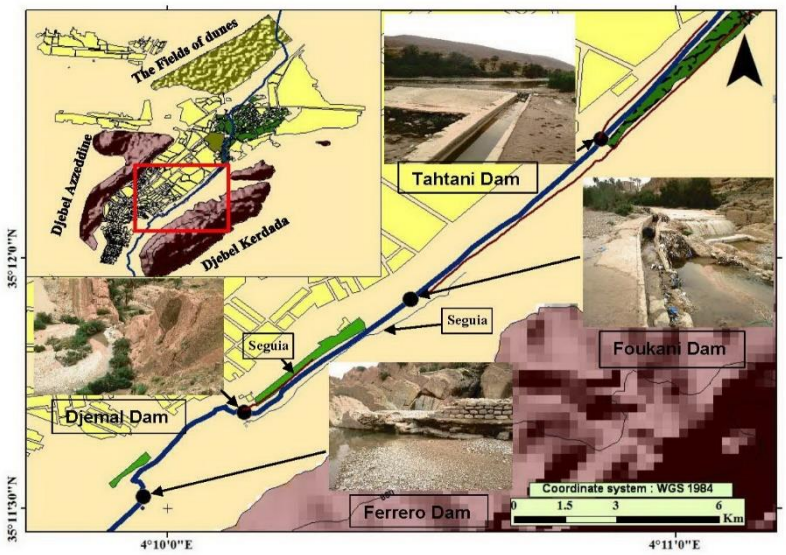

Figure 5. *Synoptic diagram of the Dam on the Boussaada oasis*

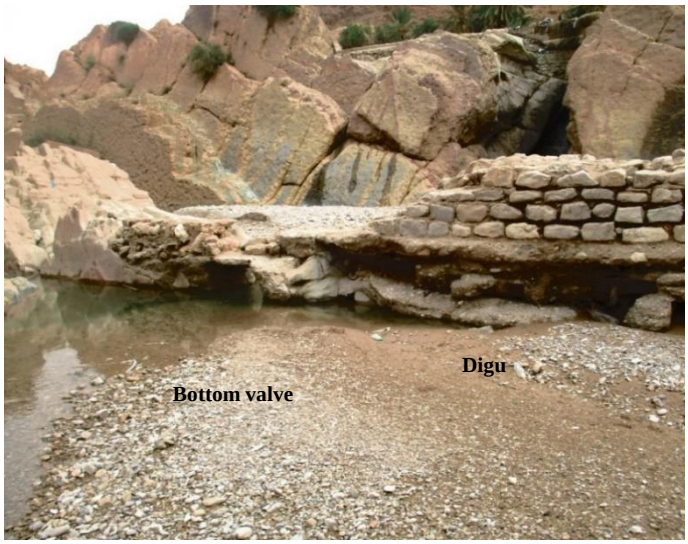

Figure 6. *A cross-sectional view of a Ferrero dam*

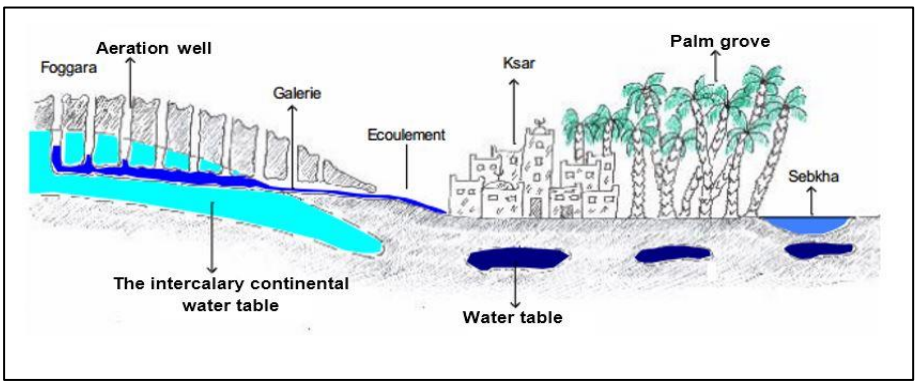

Figure 7. *Simplified diagram of an oasis at foggara (Touat oasis) [2]*

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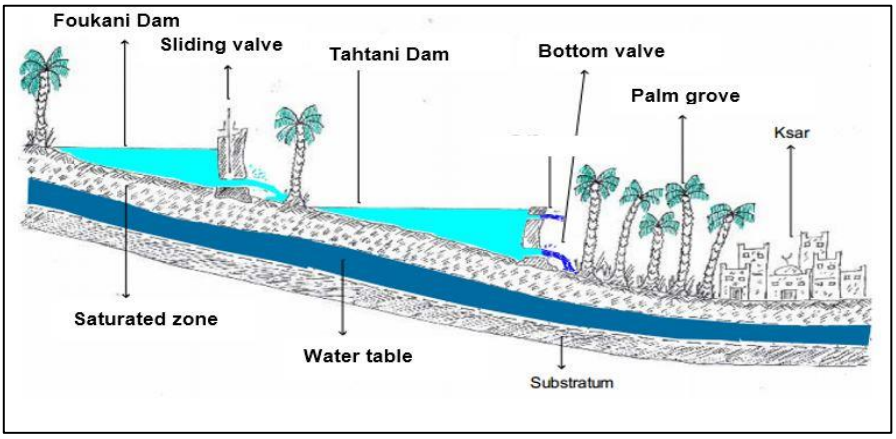

Figure 8. *Simplified diagram of the Tiout Oasis [2]*

Figure 9. *Date palms in the oasis of Boussaada*

Figure 10. *Fruit trees in the oasis of Boussaada*

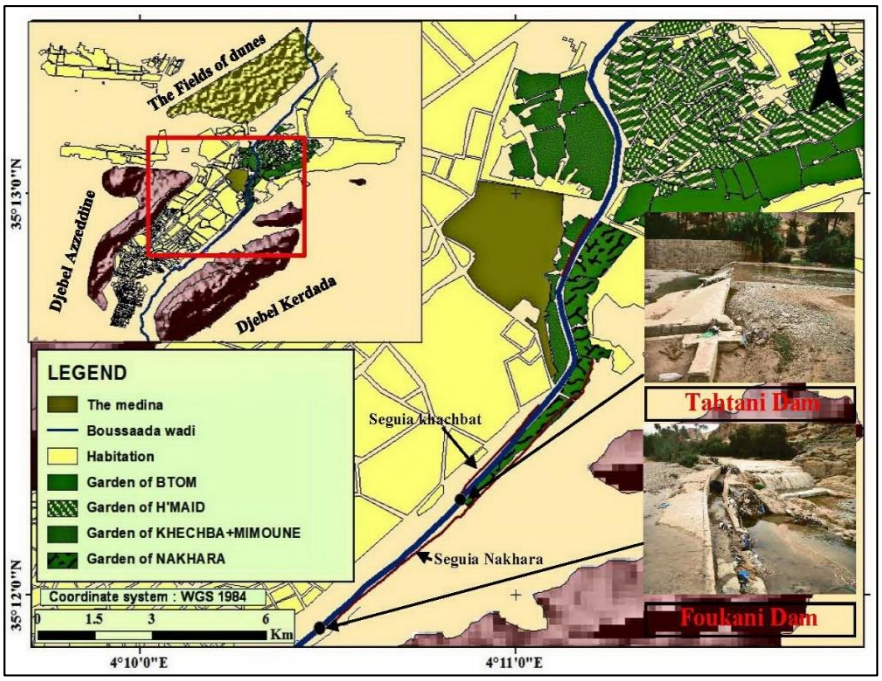

Figure 11. *Diagram of the surface area of the Boussaada palm grove*

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Figure 12. *Spring water on the left bank of the Boussaada "wadi" (valley)*

Figure 13. *Spring water at the foot of the mountain*

Figure 14. *A water source in "Wadi"(Valley) Boussaada*

3.2 Foggaras of springs

3.2.1 Foggara of spring in Small Mechria

3.2.1.1 The Ksar of Small Mechria

The ksar of Small Mechria (of 1 ha) was built during the 16th century by children of Sidi Ali al-Khalifa [9] (Figures 15 and 17). About 100 families lived in the ksar, according to the local population. The first dwellings were built near the water source. The materials used in the construction of the Ksar are rocks, and juniper wood. The Ksar was supplied with drinking water from wells. Each house of Ksar was equipped with an internal well for the domestic needs of the family (Figure 16).

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3.2.1.2 The foggara of Small Mechria

The foggara of Small Méchria was dug in this region for garden irrigation (Figure 17). In contrast to the foggara of Moghrar, which collects its water from a well [1]. This foggara collects its water from two water sources that are recharged from runoff from the peripheral mountains.

In contrast, the El Meghier foggara is more than 10 km long and equipped with more than 500 aeration wells [8]. The foggara of Petite Mechria has a gallery of several hundred meters. It has a gallery of more than 100 meters long, equipped with three aeration shafts (Figure 18).

Figure 15. *One of the three gates of the ksar small Mechria*

Figure 16. *A secured well in the ksar of small Mechria*

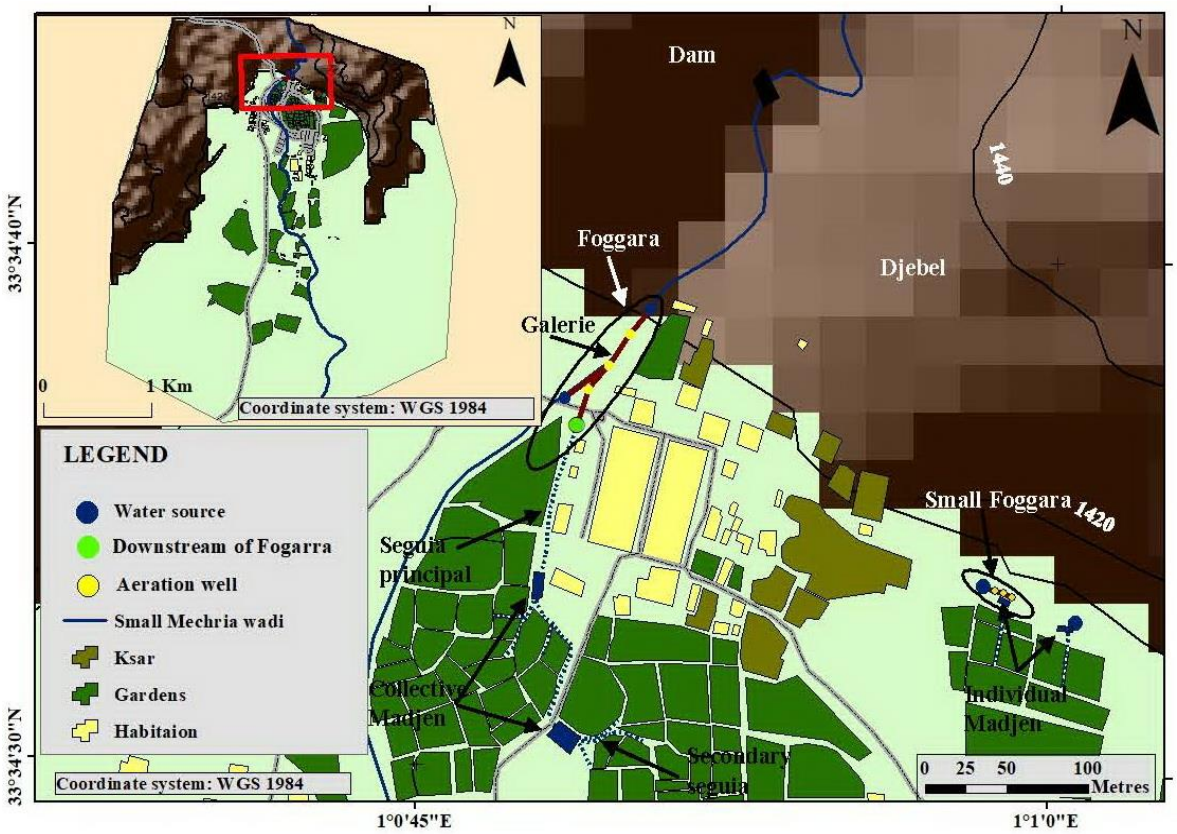

Figure 17. *Synoptic diagram representing the Foggaras in Small Mechria*

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Figure 18. *A well of the foggara in the region of Small Mechria*

3.2.1.3 Distribution network of the foggara of Small Mechria gardens

The gardens of Small Mechria have a total area of 10 ha, characterized by the diversity of types of fruits and vegetables in the gardens.

Irrigation of the gardens is carried out in series. At the outlet of the water on the downstream side of Foggara, it is channelled by the main seguia (Figures 19 and 20) up to Madjen (collective storage basin) 2, which comes after Madjen 1 (Figure 21). A network of secondary and tertiary earth seguias (Figure 22) is connected directly to the two Madjens. The sharing of irrigation water between farmers is carried out by the Hadjra method (Figure 23), which means the hourly method (Figure 24). Wells were dug in the palm grove to support irrigation with water from Foggara.

Figure 19. *Principal seguia*

Figure 20. *Secondary seguia*

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Figure 21. *Collective Madjen 1 of Small Mechria foggara*

Figure 22. *Collective Madjen 2 of Small Mechria foggara*

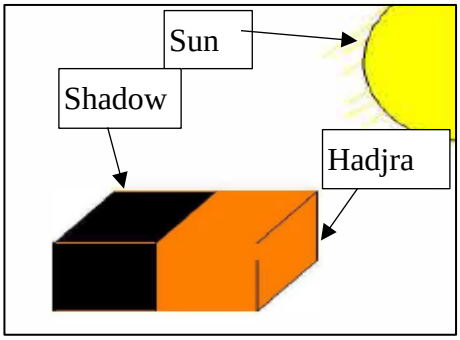

Figure 23. *Hadjra of Small Mechria*

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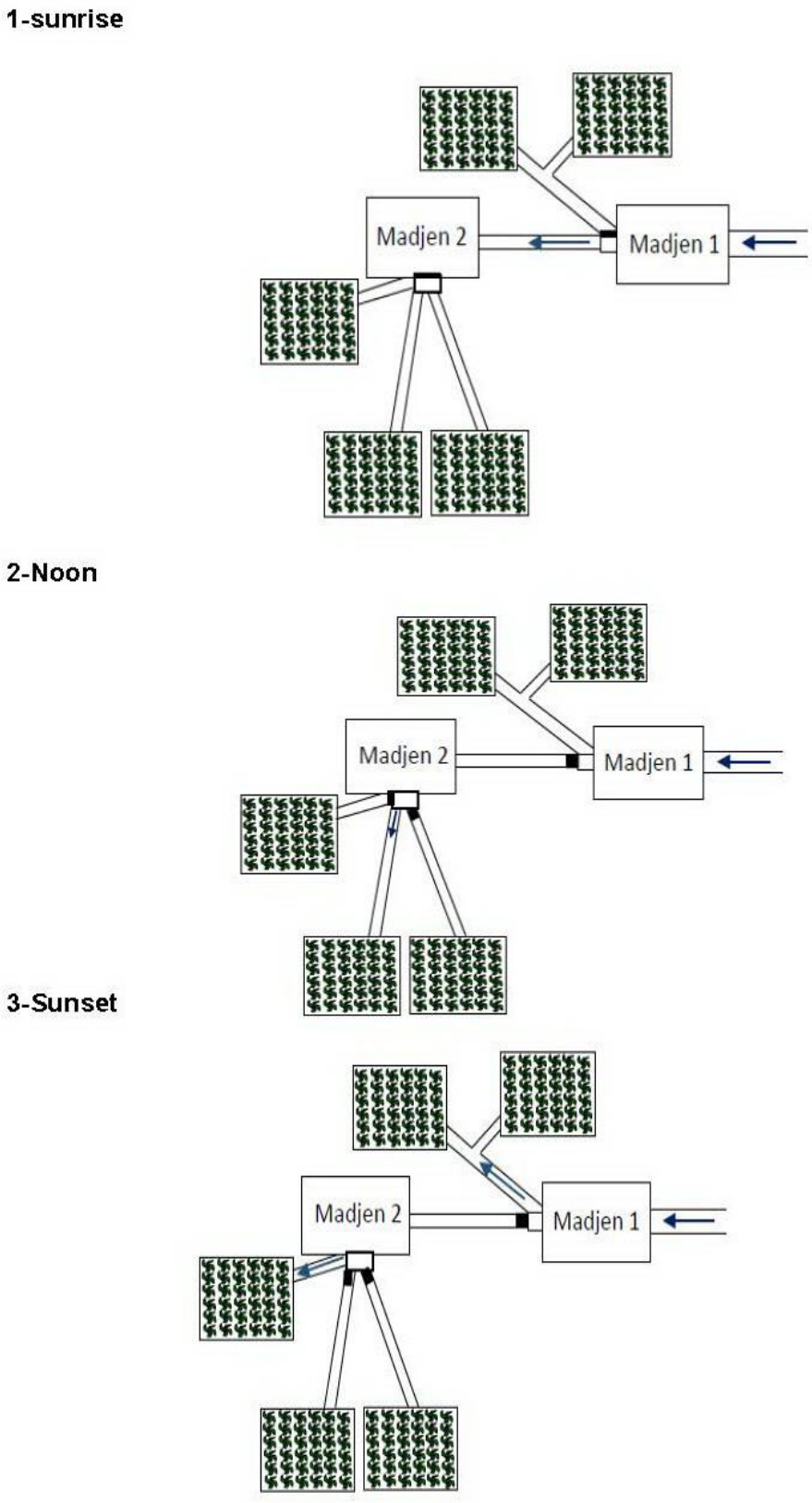

Figure 24. *Example of water distribution between owners according to towers*

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3.2.2 Foggara of spring in Stitten

3.2.2.1 The ksar of Stitten

The Stitten ksar with an area of 2.8 ha was built during the 13th century on the southern foot of the Jebel of Kessel by Mighrawa tribes [9] (Figures 25 and 26) who had settled near the water source.

3.2.2.2 The foggaras of Stitten

The foggaras of Stitten were dug in this region for garden irrigation and supply of the ksar. Two foggaras capture water partly from a single source of water that recharges from the peripheral mountains' runoff. Unlike the foggara of El Meg, whose gallery is more than 10 km long equipped with more than 500 ventilation wells, the Stitten foggara has only several hundred meters. It has a gallery of more than 100 meters in length (Figure 26).

Figure 25. *A general view of the Ksar of Stitten*

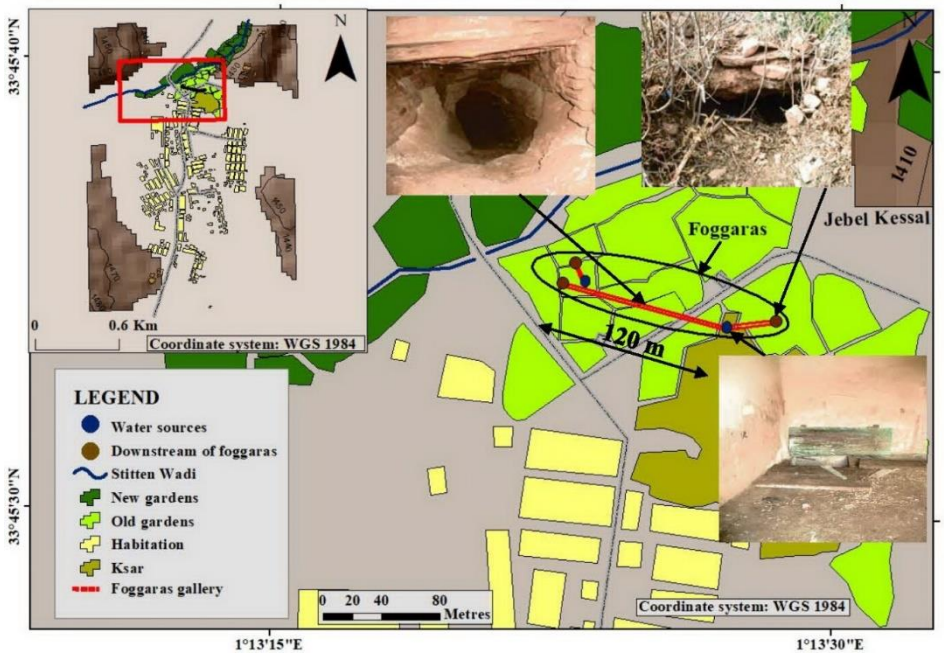

Figure 26. *Synoptic diagram representing the Foggaras in Stitten*

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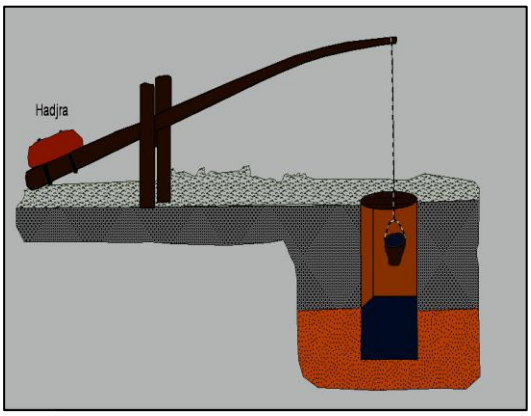
3.2.2.3 The gardens of Stitten

Stitten gardens have a total area of 10 ha (Figure 27) intended for the local population's self-development, and there are 640 gardens, various types of fruits and vegetables in this area, the sharing of irrigation water among farmers is done by the hourly method. Some wells were dug in the palm grove to consolidate irrigation by the water of the foggaras. These are the pulley and pendulum wells (Figures 28 and 29).

Figure 27. *A Garden in Stitten*

Figure 28. *A traditional well in Stitten's garden*



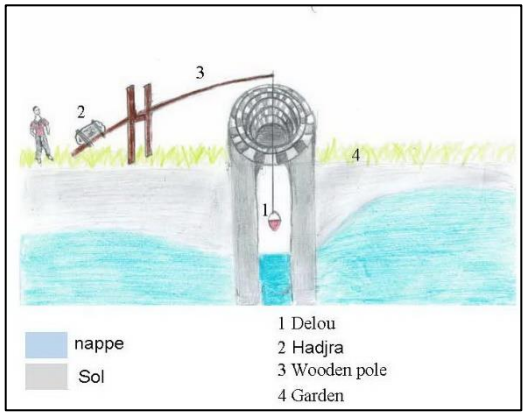


Figure 29. *Pendulum (Khottara) to irrigate the gardens of Sttiten*

3.2.3 Foggara of spring in Ain Madhi

3.2.3.1 The Ksar of Aïn Madhi

The ksar of Aïn Madhi with a surface area of 2.5 ha was built during the 12th century (Figure 30). It was the Sidi Aissa and Sidi Mohamed families who first settled near the water source of Aïn Madhi [10].

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Figure 30. *Bab Sakia of Ksar of Aïn Madhi*

3.2.3.2 The foggara of Aïn Madhi

The foggara of Ain Madhi was dug in this region for the irrigation of gardens and feeding of ksar (Figure 31), it is different from the foggaras of Touat and Gourara, and it is the same as the foggara of Moghrar. It consists of a water source (Figures 32 and 33) that represents the catchment well and a gallery that is 5 km long equipped with some aeration wells.

Figure 31. *Place where local people consume water*

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Figure 32. *Foggara water spring of Ain Madhi*

3.2.3.3 The gardens of Aïn Madhi

The gardens of Aïn Madhi have a total area of 40 ha and are intended for the self-development of the local population, in addition to 100 gardens, various types of fruits and vegetables in this region, the irrigation turn between owners is carried out according to the concept of time.

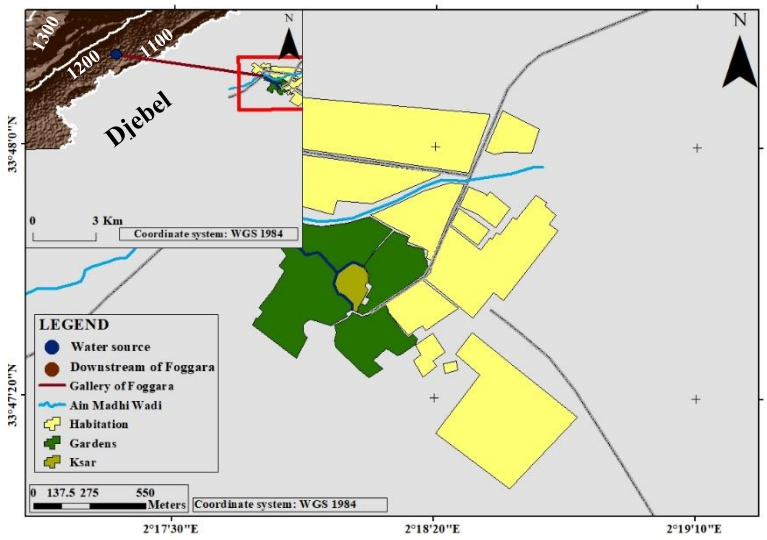

Figure 33. *Synoptic diagram representing the Foggaras in Ain Madhi*

3.3 Problems of degradation of the traditional system

3.3.1 Drying of water sources

The emergence of drillings equipped with a pumping system in the early 1980s to irrigate new agricultural land and provide drinking water to the population caused a drop in the water table and, therefore, the drying up of most of the water sources, which led to the gradual abandonment of the traditional system.

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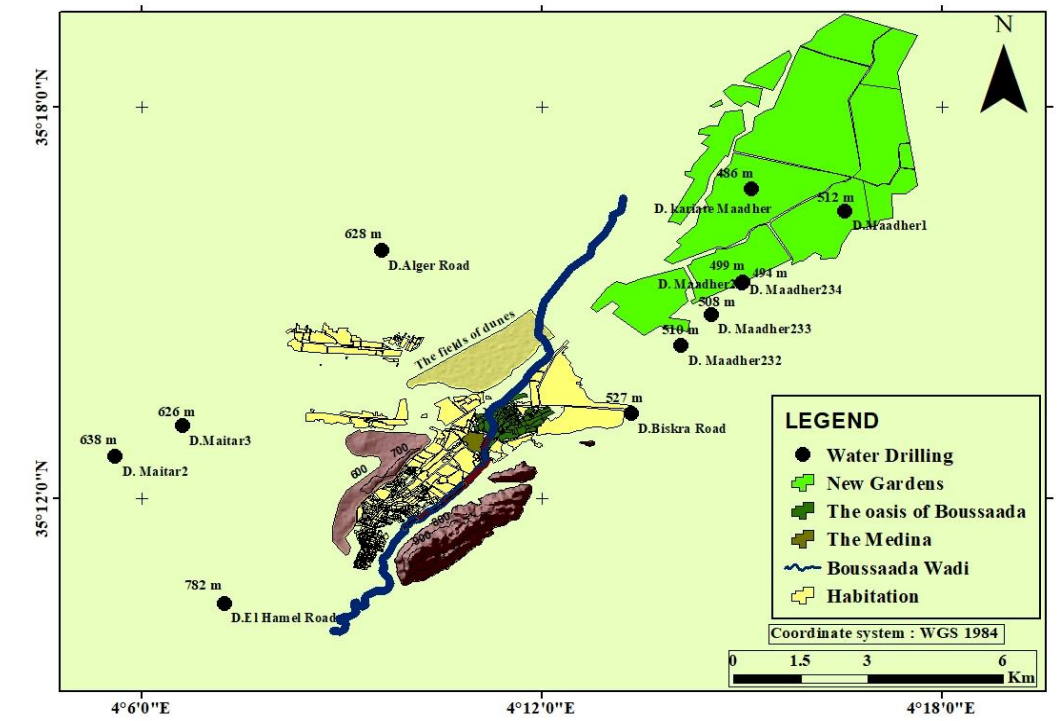

***Figure 34**. Distribution of drilling in Boussaada (modified according to [11])*

***Figure 35.** Drying of the water source in Boussaada*

***Figure 36.** Drying of the Foggara of Small Mechria*

***Figure 37.** Drying of the Foggara of Stitten*

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3.3.2 Silting of dams

Decreasing flow from water sources in these areas has prompted farmers to build dams to overcome the water deficit. Indeed, in the early 1960s, a few dams were built in the regions, but the dams at each flood were held back by deposits of sand and sediment (Figures 38–41), the main reason for obstructing the flow of water into the Sakia Although farmers tried to protect it by covering it with flat rocks in Boussaada (Figure 42).

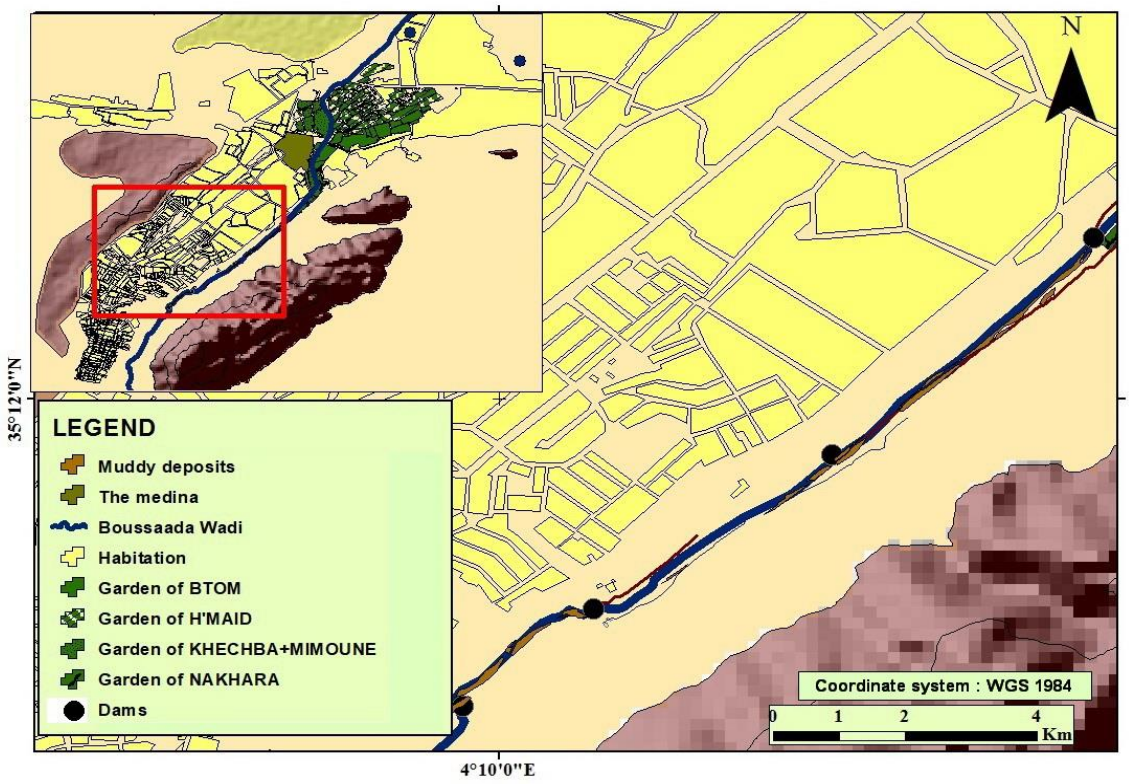

Figure 38. *Probable pattern of muddy deposits in the dam reservoir in Boussaada*

Figure 39. *Small Mechria dam collapsed by a flood in 1997*

Figure 40. *Sandy deposit in the reservoir of the Stitten dam*

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Figure 41. *A large part of the dam suffers from siltation*

Figure 42. *Seguia covered with flat rocks in Boussaada*

4 CONCLUSION

As we mentioned at the beginning of this study, water collection techniques have evolved over more than nine centuries, allowing the development of the oases of Boussaada and the gardens of Ain Madhi, Stitten, and Small Mechria, depending on the abundance of water. However, the emergence of modern technologies such as motor pumps in the early 1980s contributed significantly to increased agricultural production. Still, this has hurt the environment, and made most water sources disappear. On the community side, the problem of inheritance played a significant role in cutting the culture of teamwork, which gradually contributed significantly to abandoning the ancestral system. All these problems necessitate that we preserve the remainder of the ancestral heritage and find an intermediate solution that guarantees the right of both the traditional and the modern techniques to continue.

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