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The Damaging Earthquake of 9 October 859 in Kairouan (Tunisia): Evidence from Historical and Archeoseismological Investigations

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Abstract

The city of Kairouan, the capital of the Aghlabides Dynasty (A.D. 800–909), and its surrounding areas were affected by a damaging earthquake on 8 Rajab 245 Hijri (9 October 859). Contemporaneous accounts by local travelers to the Abassides Califat (A.D. 750–1258) and reported by the chroniclers and historians Al Baghdadi (1980) and Al Tabari (A.D. 838–923) (1967) describe the damage to the city and report that 13 villages experienced extensive destruction, leading to a large number of people homeless. In the city of Kairouan, the dome and other holy places of the Great Mosque (minbar and mihrab), houses, fortifications, and bridges all suffered severe damage. The aqueduct that supplied Kairouan with fresh water from the western mountains was badly damaged at a location about 20 km west of the city. New archaeoseismic field investigations of the aqueduct using laser scanning and radiocarbon dating characterize the damaged features. Recent field investigations in the region taking into account the construction types and the inferred damage distribution suggest a macroseismic intensity reaching IX–X Medvedev–Sponhauer–Karnik scale. The seismotectonic context suggests a seismic source along the major Sbiba east–west-trending transpressive fault that includes the Cherichira, Sfaia, and El Baten folding system near Kairouan. An active fault system affecting late Quaternary units made up of ~30–kilometer–long thrust-related en echelon folds associated with the east–west-trending fault is identified and characterized as seismogenic at a location about 20 km west of Kairouan.

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Introduction

Historical earthquakes in Tunisia were the focus of several research programs due to the continuous written record of seismic activity since Phoenician and Roman times (e.g., Ambraseys, 1962; Taher, 1979; Vogt, 1993; Guidoboni *et al.*, 1994; El Mrabet, 2005; Kharrat *et al.*, 2018). The moderate seismicity of Tunisia is located at the active plate boundary between Africa and Eurasia (Meghraoui and Pondrelli, 2012; Fig. 1a). The north-northwest–south-southeast to north–south convergence between the two plates being estimated at 5–6 mm/yr, the active deformation is distributed throughout about 70% of northern Tunisia (N. Bahrouni *et al.*, unpublished manuscript, 2019, see Data and Resources). Seismotectonic studies have identified active faults in central Tunisia (Bahrouni *et al.*, 2014), but the instrumental seismicity of the Kairouan region since A.D. 1900 is still poorly documented due to the lack of a dense seismic network in Tunisia until 1989 (Hfaiedh and Allouche, 1993). Since then, seismic events with $M_w > 2$ have been recorded in central Tunisia from the Algerian boundary in the west to Sousse along the oriental Mediterranean coastline; however, uncertainties in the locations of hypocenters are still high (>10 km; Kharrat *et al.*, 2018).

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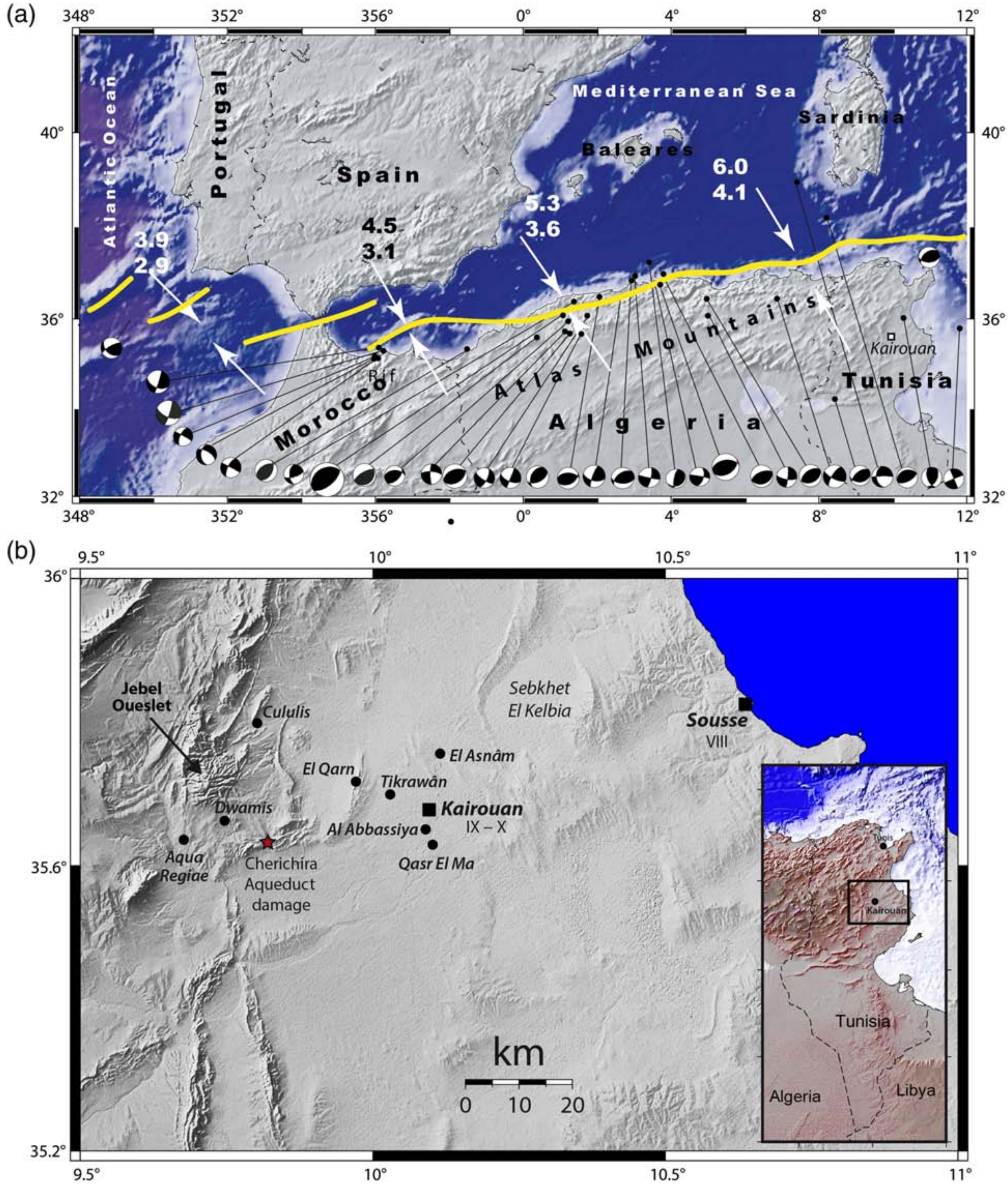


Figure 1. (a) Plate boundary (yellow line) and convergence rates (black and white numbers in mm/year) in North Africa (Meghraoui and Pondrelli, 2012). Focal mechanisms are from Global Centroid Moment Tensor. Topography and bathymetry from General Bathymetric Chart of the Oceans. (b) The city of Kairouan (black square) in central Tunisia (see inset), the site of the A.D. 859 earthquake, according to two contemporaneous chroniclers Al Baghdadi (1980) and Al Tabari (A.D. 838–923) (1967). Background topography is from Farr and Kobrick (2000). Severe damage to the city of Kairouan and 13 neighboring villages is reported in the Al Baghdadi and Al Tabari contemporaneous documents; circles give the locations of eight villages (among 13) often cited in historical documents and likely damaged by the earthquake. The star indicates the damage location of the Cherichira Aqueduct that served to supply fresh water from Jebel Oueslet to Kairouan (see also Fig. 2b). The intensities IX–X and VIII Medvedev–Sponhauer–Karnik scale are attributed to the cities of Kairouan and Sousse, respectively, based on the reported damage descriptions and important reconstructions beginning from A.D. 860 (Al Tabari [A.D. 838–923], 1967; Golvin, 1968; Al Baghdadi, 1980; Mahfoudh *et al.*, 2004). The color version of this figure is available only in the electronic edition.

The city of Kairouan, previously known as the Roman town *Fossatum*, was founded by Okba Ibn Nafî in A.D. 670 and established as a capital by the Aghlabides Dynasty (A.D. 801–909). Kairouan, the first established city of the Islamic Maghreb, was considered by the Califat of Baghdad and the Abbassides Dynasty as the fourth most important holy city after Mecca, Medina, and Jerusalem. Kairouan is well known for its impressive Great Mosque built in A.D. 836, with a 31.5-meter-high minaret and 3.5-kilometer-long city walls (Golvin, 1968). The Great Mosque is on the UNESCO world heritage list since 1988. The water supply was provided either through rainwater channelled into underground cisterns or through the ~35-kilometer-long Cherichira Aqueduct, which brought fresh water from the Oueslet Mountains to the west (Figs. 1b and 2a,b).

Studies on the occurrence of the A.D. 859 earthquake and related damage in the Kairouan region is so far primarily based on the examination of contemporaneous documents from the historian-chroniclers Al Baghdadi who died in A.D. 860 (reference edited in 1980) and Al Tabari A.D. 838–923 (reference edited in 1967). Field investigations using archeoseismological approaches (Stiros and Jones, 1996; Hinzen *et al.*, 2011) suggest earthquake-induced damage of the Cherichira Aqueduct and the Kairouan city mosque. The analysis of historical documents indicates severe damage to mosques, houses, walls and bridges, and buildings in several villages in the proposed epicentral area (Younes, 2009). In addition, there is evidence of important building reconstructions and renovations beginning in the year A.D. 860 (Mahfoudh *et al.*, 2004). Kairouan is also known for its large, still-existing circular water-basin reservoirs built in A.D. 862 (Golvin, 1968; Mahfoudh *et al.*, 2004).

Beside the A.D. 859 seismic event described in contemporaneous reports, other historical earthquakes have affected the Kairouan region. These occurred in A.D. 911–912 (Medvedev–Sponhauer–Karnik [MSK] = VII; Taher, 1979; Kharrat *et al.*, 2018) according to Ibn Al Adhari [1241–1295] (1948; died 1295) and in A.D. 1040 according to Ibn Aibek (Younes, 2009). Other historical seismic events are also reported by Ambraseys (1962, 2009) and Guidoboni *et al.* (1994). However, the instrumental seismicity shows that no moderate earthquake with $M_w > 5$ has occurred in the past century.

In this article, we present historical and archeoseismological support for the occurrence of an earthquake on 9 October 859 that severely damaged the city of Kairouan and the surrounding region. The contemporaneous documents that describe the earthquake occurrence are presented along with a detailed account of damaged buildings in the city. Aiming at a complete and detailed account on the earthquake, we study the contribution of contemporaneous and noncontemporaneous documents to the Tunisian seismicity catalog. In the epicentral area, important damage can be inferred from postearthquake reconstructions and from the dating of the interruption of the Roman–Aghlabides Aqueduct. The earthquake damage that affected the main villages in the mesoseismal area and as far as the city of Sousse helps constrain the overall size of the earthquake. Finally, we discuss the potential seismic source location and its seismotectonic characteristics.

The 9 October 859 Earthquake: Historical Context

As a holy city, Kairouan was an important urban area linked to the Abbassides Dynasty (750–1258); all reports on the political and economic situation of the region including natural hazards (i.e., earthquakes, flooding, storms) were regularly sent to Baghdad. Two contemporaneous historians and chroniclers, Al Baghdadi and Al Tabari, report on the earthquake with descriptions from Maghrebian traders and travelers recorded at that time in the book of merchants. Both historians add that a strong earthquake affected the city of Kairouan, and Al Tabari notes the date of 8 Rajab 245 Hijri (H) that corresponds to A.D. 9 October 859. The mention by the historians is as follows.

Al Baghdadi (ed. in 1980; Ilse Lichtenstädter, 1939), also quoted by Ibn al Jawzi (1116–1200) (1987), reports that (translation from Arabic): “During the ruling of Al Mutawakil (822-861) in 240H, the book of merchants mentions that severe damage affected 13 villages from Kairouan region, leaving only 42 black men alive; they searched for refuge in the city but they were expelled under the accusation of being cursed, which lead the local governor to the building of shelters outside the city for them.”

> " وفي خلافة المتوكل سنة أربعين ومائتين جاءت كتب التجار (تجار المغرب) أن ثلاث عشرة قرية من قرى القيروان خسف بها فلم ينج من أهلها الا اثنان وأربعون رجلا سود الوجوه، فأتو القيروان فأخرجهم أهلها وقالوا: أنتم مسخوط عليكم، فبنى لهم العامل حفيرة خارج المدينة فكانوا فيها "

Al Tabari also reports that “A large earthquake occurred in that year (245H) in the Maghreb region and caused destruction of fortifications, houses, and bridges; the Calif Al Mutawakil ordered the distribution of three thousand dirhams (€ ~ 7000) for each citizen as compensation to the damage of their houses.” Kairouan being the first capital city in Islamic Northwest Africa, it often takes the name of the Maghreb (literally the sunset, Al Gharb being the west).

> " وزلزلت في هذه السنة بلاد المغرب حتى تهدمت الحصون والمنازل والقناطر، فأمر المتوكل بتفرقة ثلاثة آلاف درهم في الذين أصيبوا بمنازلهم "

We note here that Al Baghdadi (1980) reports on an earthquake as among the main catastrophic events that occurred during the 240H decade in the Abbasid Caliphate. Subsequently, this date was erroneously reported as the date of the earthquake by several authors (Al Suyuti [1445–1505], 1971; Ibn al Jawzi [1116–1200], 1987). However, Ibn Al-Athîr (1160–1233) (1872) relied on Al Tabari who also reports 8

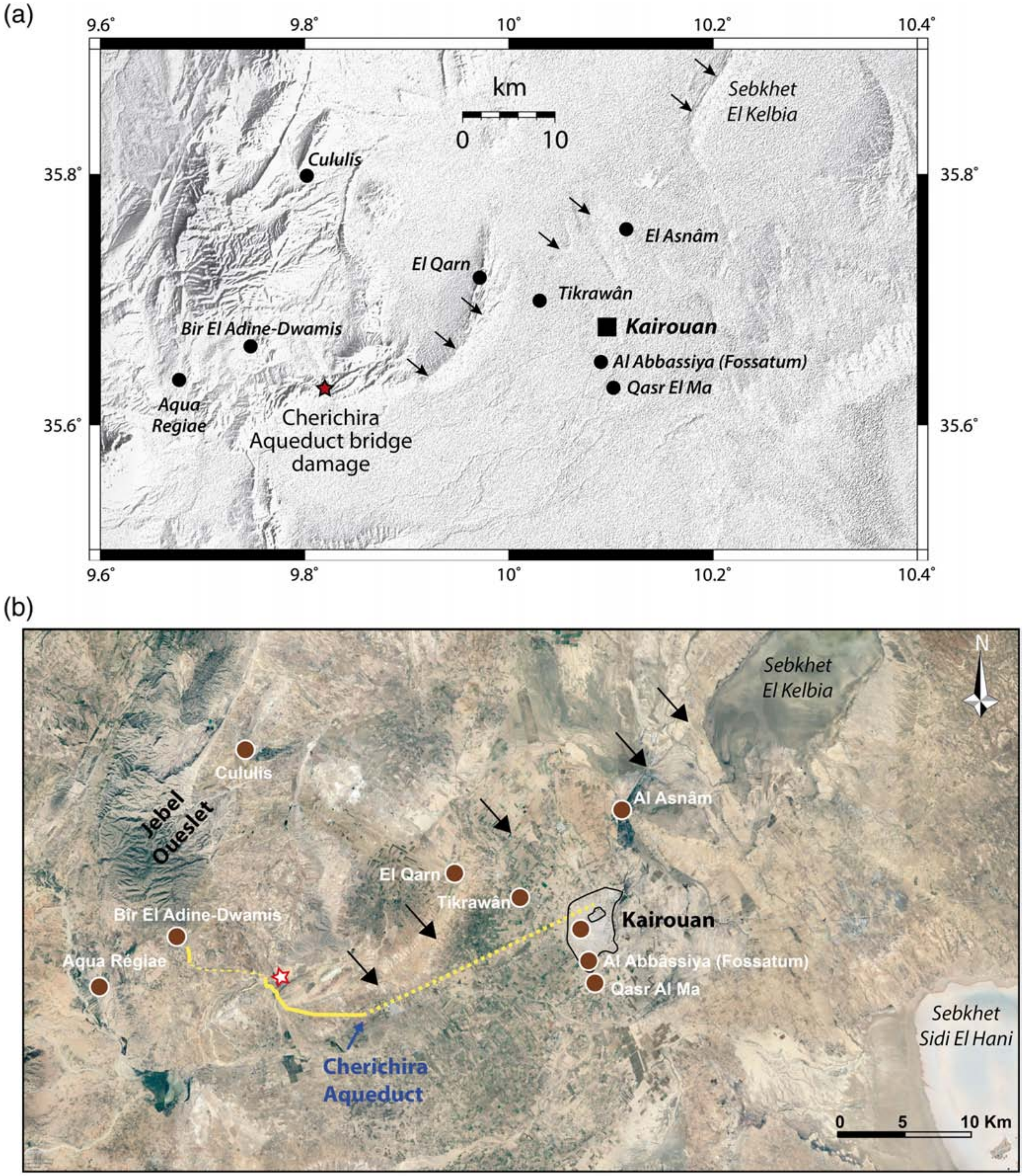


Figure 2. (a) The epicentral area of the 9 October 859 (8 Rajab 245 Hijri) earthquake that affected the city of Kairouan and villages in the region. Circles indicate the locations of villages that were probably damaged by the earthquake. The star indicates the damage location of the Cherichira Aqueduct (see also Fig. 8). Arrows show a fault trace as a potential seismogenic structure responsible for the earthquake. Background topography is from Farr and Kobrick (2000). (b) Google Earth image with the aqueduct path (yellow line). The continuous trace is the presently visible aqueduct building, while the dashed line is the inferred aqueduct from remaining aqueduct ruins. The aqueduct brought fresh water from Jebel Oueslet to the city of Kairouan and the star is the location of the damaged aqueduct bridge. Circles are the eight identified villages where only some ruins remain probably due to the A.D. 859 earthquake damage. Arrows show the fault trace which is the potential seismic source. The color version of this figure is available only in the electronic edition.

Rajab 245H for the same event. The A.D. 859 historical earthquake of Kairouan and related damage in the epicentral area are cited twice by Ibn al Jawzi (1116–1200) (1987, 1997) who quotes the book of Maghrebian merchants as cited by Al Baghdadi (1980). Furthermore, all details already mentioned by chroniclers and local witnesses are later repeated by other historians such as Ibn Al Athîr (1160–1233) (1872), Ibn Adhari (died 1295), Ibn Taghribirdi (1411–1470) (1963), and Al Suyuti (1445–1505) (1971).

Figure 3. Open air cistern also called Feskiya of Bab Tunis in Kairouan. Water reservoirs like this were built in early A.D. 860 due to a water shortage. The diameter is almost 130 m, and it is about 5 m deep. The color version of this figure is available only in the electronic edition.

Damage Account and Reconstruction

In A.D. 860 and the following years, the local governor Al Amir Abou Ibrahim Ahmed (who ruled Kairouan from A.D. 856 to 863) conducted important reconstruction and repair work in Kairouan and neighboring areas (Solignac, 1952; Mahfoudh *et al.*, 2004). As the city suffered from a severe shortage of fresh water in A.D. 860, probably due to the A.D. 859 earthquake and damage to the Cherichira Aqueduct, the local governor dedicated 300,000 dirhems (around € 700,000) to the construction of an open large circular water cistern (about 130 m in diameter and 5 m deep) for the city water supply, a historical masterwork also called "Feskiya" of Bab Tounes (Fig. 3; Golvin, 1968).

According to Al Baghdadi ((1980), in the city of Kairouan the dome and other holy places (minbar and mihrab) of the Great Mosque, the houses, fortifications, and bridges suffered severe damage. Golvin (1968) reports on an observation of structural failure and related important repairs of the double arches in the nave of the Great Mosque from A.D. 862 to 864 (Figs. 4 and 5).

Although the Great Mosque was the object of several reconstructions and restorations (Ibn Taghribirdi [1411–1470], 1963; Golvin, 1968), the most important reconstruction work (and in particular installation of the duplicate columns) was conducted from A.D. 860 to 863 by the local governor Ibrahim Ahmed. These duplicate columns are illustrated in a poster hanging in the Mosque that shows a significant and clear difference when compared to the previous Ziyadat Allah façade with its single column and small arches. The retrofitting of the Great Mosque can be observed in almost all pillars and arches surrounding the inner courtyard. Evidence of repaired damage is obvious near the minaret in the asymmetric arches and walls clamped with iron hooks (Fig. 4). Replaced monolithic columns (made of limestone or granite), doubled since A.D. 860 (Golvin, 1968), show unusual shifts of height of the new columns that were often adapted with additional stone pieces (Fig. 5a–d).

Figure 4. Two retrofitted arches in the Kairouan Great Mosque. The two retrofitted arches show different structures with the lower left structure and distorted right arch. Pillar tops are not at the same level, and the two structures are clamped with three iron hooks. The color version of this figure is available only in the electronic edition.

Both Al Tabari (A.D. 838–923) (1967) and Al Baghdadi (1980) report that 13 villages were damaged in the Kairouan region. Based on *in situ* witnesses of local archaeological remains, old buildings, and historical documents, we conducted field investigations to evaluate the possible extent of earthquake damage. The heavy damage of the Roman towns *Cululis* and *Aqua Regiae* (Fig. 6), and the disappearance of several medieval settlements (see the eight old villages in Fig. 2b) suggests that the earthquake effects extended well beyond the city of Kairouan

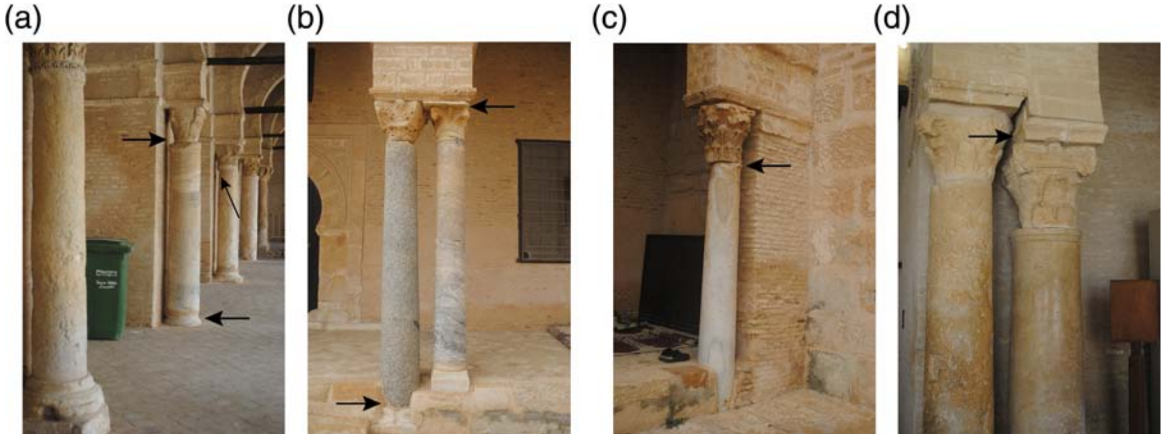


Figure 5. Trace of column retrofits in the Great Mosque of Kairouan with double column pillars dating from A.D. 860 (Golvin, 1968), indicating reconstruction probably after the earthquake damage in A.D. 859. (a) Upper arrows point to the offsets in the pillars and the lower arrow shows the absence of the base of a pillar; (b) configurations of different pillars with adjunction of a piece (upper arrow) and unequal pillar bases (lower arrow); (c) offset pillar (arrow), also showing rebuilding around a wall base; and (d) detail of two different pillars indicating reconstruction. The color version of this figure is available only in the electronic edition.

Figure 6. Damaged Roman city of Cululis (now Ain Jloula, see location in Figs. 1 and 2a,b). Arrows on frontal wall show the different building stones with evidence of reconstructions and possible repeated earthquake damage. The central arrow shows collapsed large blocks. The color version of this figure is available only in the electronic edition.

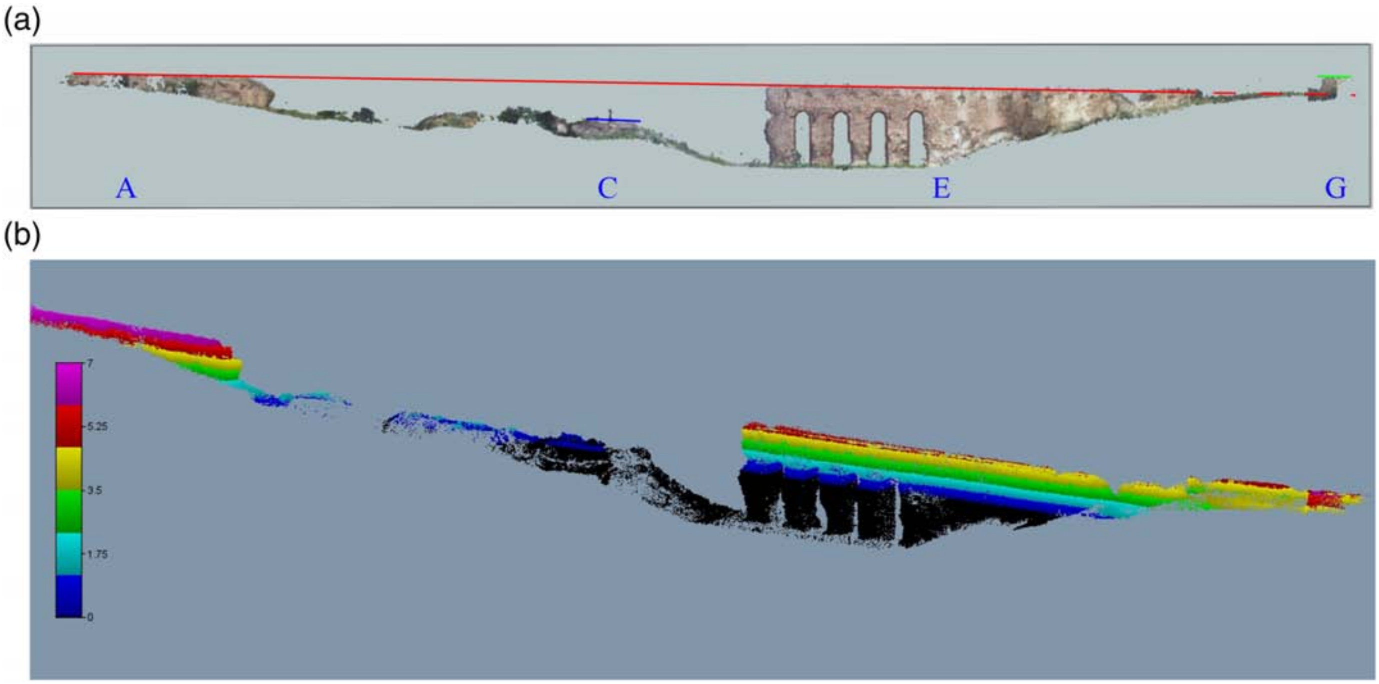
Figure 7. (a) Inscription “على يدي الخادم فتاتة في سنة خمس وأربعين ومائتين” meaning “On behalf of the servant Fatata in the year 245H” that commemorates the reconstruction of the fortifications in A.D. 859–860 on the southern wall of the city of Sousse; (b) traces (arrows) of repairs on the fortification wall of Sousse; and (c) repaired diagonal fracture (arrows) in a tower of the Sousse city fortification. The color version of this figure is available only in the electronic edition.

limits and reached as far as the coastal city of Sousse (ex. Justinianopolis, later on named Susa; Fig. 1). A still visible stone engraving on the Sousse city wall (in Arabic Coufi writing style) commemorates the reconstruction of the southern wall and related fortifications in A.D. 859 (Fig. 7; Laporte, 2015). Sousse being located about 40 km east of Kairouan (Fig. 1), the reconstruction of damaged fortifications (Fig. 7) immediately after the occurrence of the earthquake supports a large extent of the mesoseimal zone. Other important concomitant rebuilding of the lighthouse, mosque minarets, and battlements along with the retrofitting of old houses are all dated to have started in A.D. 859 (Laporte, 2015). The coincidence between the earthquake date and significant reconstructions in A.D. 860–863 indicates the severe level of seismic damage in A.D. 859. In comparison with other reported large earthquakes in central coastal Tunisia (Kharrat *et al.*, 2018), the size and extent of damage in the Kairouan region, 13 villages, and coastal Sousse suggest a maximum intensity of IX–X on the MSK macroseismic scale for the A.D. 859 earthquake.

Figure 8. (a) The aqueduct bridge with its edges (arrows) crossing the Cherichira River; (b) ~25-meter-high aqueduct bridge with 2.9 × 2.9 m pillars built during the Roman time in Tunisia (146 B.C.–A.D. 423) and the Aghlabides period (A.D. 800–909); (c) the Roman and Aghlabides Aqueduct exposures; and (d) top of the aqueduct with a canal on the bridge. The color version of this figure is available only in the electronic edition.

The Damaged Cherichira Aqueduct

The water supply to major cities in medieval times was an important factor of urban development. The city of Kairouan reached about 100,000 inhabitants in the ninth century and needed a constant access to fresh water (Mahfoudh *et al.*, 2004). The Cherichira Aqueduct, a previously Roman structure, provided fresh water to Kairouan and surrounding fields from Jebel Oueslet, located ~35 km west and northwest (Fig. 2b). The existing structure shows in some sections two main superposed canals, the first being Roman and the second Aghlabides (Fig. 8c). The aqueduct has a typical Roman design;



it is either buried, embedded or carved into geological units, or built upon the ground, and also is elevated as a bridge when crossing the ~170-meter-wide Cherichira River valley (Figs. 2b and 8a,b). The ~400-meter-long bridge reaches about 25 m high with basement stones ~1 m long, over ~0.5 m wide and height forming 2.9 × 2.9 m (equivalent to 2 *passus* in Roman measures) size pillars (Fig. 8b). The northern half of the aqueduct bridge is damaged and collapsed where it crosses the valley, leaving the two edges quasi unbroken. Often located upon the Roman structure, the Aghlabides canal can be easily identified with its ~1-meter-high arched mortar edges (Fig. 8a–d).

As a first step to further explore the history of the damaged aqueduct bridge, we made a terrestrial laser scan survey of the bridge structure. The resulting 3D model (Fig. 9) helps reconstruct the different building stages of the structure, particularly those of the Roman versus Aghlabides periods, that will form the basis of a dynamic analysis to evaluate possible damage scenarios. In this contribution, we were mainly interested in characterizing the period of aqueduct collapse and interruption of the water supply to test its synchronicity with the historic reports of the earthquake. We selected a site ~800 m southeast of the bridge where the canal is damaged and filled with sediments (Fig. 10). The new excavation clearly reveals the aqueduct frame made of white mortar with its inner part filled with a succession of silty-sandy units mixed with fine and coarse gravel. The accelerator mass spectrometry (AMS) radiocarbon dating of a mortar sample collected from the aqueduct wall gives A.D. 771–965 (2σ 95.4%), a large bracket for the construction time, but a result that is in agreement with the aqueduct (re-)opening in the early ninth century during the Aghlabides ruling time (Solignac, 1952; Mahfoudh *et al.*, 2004).

Figure 9. (a) Orthographic view from the west of the laser scan model of the Cherichira Aqueduct. Blue letters indicate different sections of the structure. The red line connecting sections A and E has a slope of 0.88°. Blue and green lines indicate the top level of sections C and G, respectively. (b) View from the southwest with scan points coloured by elevation level (the zero value of the scale has been arbitrarily selected). The color version of this figure is available only in the electronic edition.

The filling of the Aghlabides canal with a succession of deposits implies that (1) the end of aqueduct function was coeval with the early deposits in the canal, and (2) an AMS radiocarbon analysis of a charcoal sample in early deposits provides dates of A.D. 892–1014 (2σ 95.4%), which postdates the A.D. 859 earthquake occurrence by a few decades.

Discussion and Conclusion

The city of Kairouan and its surrounding region were affected by an earthquake in A.D. 859 that caused significant damage. Several contemporaneous and subsequent chroniclers and historians have provided descriptions of the damage in the Kairouan region and how it left a large number of people homeless. It was also reported that a sequence of strong earthquakes continued for three days, and homeless villagers from the countryside requested refuge in the city of Kairouan. Although Guidoboni *et al.* (1994) and Ambraseys (2009) mention the earthquake's occurrence in the Maghreb, the earthquake is reported by both authors as doubtful because its related historical effects had not been sufficiently studied by seismologists and historians. The recently studied Arabic documents of contemporaneous chroniclers and the history

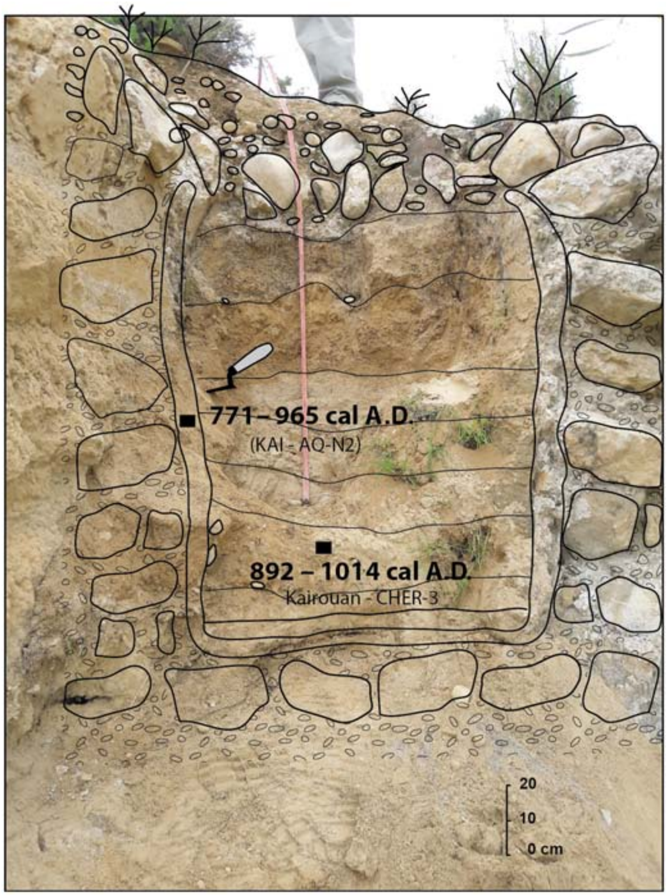


Figure 10. Section of the buried Aghlabides Aqueduct filled with alluvial and colluvial deposits. Black boxes indicate the locations of charcoal samples with the oldest calibrated radiocarbon dates. The color version of this figure is available only in the electronic edition.

of Kairouan city report details on the homeless inhabitants, the financial compensation sent by the Calif of Baghdad, the severity of damage to the Great Mosque, and reconstructions of buildings in the city of Kairouan and in the surrounding region (Solignac, 1952; Golvin, 1968; Mahfoudh *et al.*, 2004; Laporte, 2015).

As reported by Al Tabari (A.D. 838–923) (1967) and taking into account the descriptions of the book of merchants according to Al Baghdadi (1980), the earthquake badly affected the city of Kairouan and caused significant damage in 13 villages. After some local investigations, eight villages that probably were affected by the earthquake could be identified, such as Ain Jloula (formerly the Roman town of Cululis), Haffouz (Aqua Regiae), Bir El Adine (Dwamis), El Qarn (El Baten), Tikrawân, Qasr El Ma, Al Abbassiya, and El Moutbasta (El Asnâm), all located to the north and northwest of Kairouan in Figure 2b.

Our investigations revealed also indirect accounts of earthquake damage through important reconstruction projects in the cities of Kairouan and Sousse from A.D. 859 to 864. Several more recent authors (Solignac, 1952; Golvin, 1968; Mahfoudh *et al.*, 2004; Laporte, 2015) provide details on the main reconstructions and their dating, which coincides with the aftermath of the A.D. 859 earthquake.

Another important observation is the damaged Roman–Aghlabides Aqueduct at Cherichira and the radiocarbon dating of its infilling that shortly postdates the A.D. 859 earthquake. Here, the isotopic dating suggests that the use of the aqueduct was ended during the time of the Aghlabides rule. It appears reasonable to conclude that the construction of an important water reservoir in Kairouan in A.D. 860 was a reaction to compensate for the broken water supply due to the earthquake damage to the aqueduct.

We may also note that although Bahrouni *et al.* (2014) have attributed the damage of the aqueduct bridge to earthquake activity, their inference of a faulted aqueduct does not appears to be valid. Further analysis of a recent 3D laser scan model of the damaged bridge will help evaluate possible damage scenarios. The trace of a northeast–southwest-trending reverse fault is delineated by a linear fault scarp at the edge of the Sebkhet El Kelbia (Fig. 2b). This ~40-kilometer-long reverse fault could have caused the A.D. 859 earthquake and its related damage, but these inferences need paleoseismological investigations. The city of Kairouan and the surrounding region being an important urban and rural agglomeration attracting an increasing number of visitors, the earthquake activity, and related active tectonics should be the focus of a research program necessary for an improved seismic hazard and risk assessment.

Data and Resources

Historical documents referenced in this article are from the Archives Section of the Institut National du Patrimoine, Tunis. The maps of Figures 1 and 2 were prepared using the General Mapping Tools software (Wessel and Smith, 1998), and the map of Figure 3 is from Google Earth satellite imagery. The unpublished manuscript by N. Bahrouni, *et al.* (2019) "Active tectonics and GPS data analysis of the Maghrebian thrust belt and Africa-Eurasia plate convergence in Tunisia," submitted to *Tectonophysics*.

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References

Old references

Al Baghdadi (died 860) (1980). *Kitāb al Mukḥabbir*, Ed. Dar al-afaq al-jadida, Beirut, Lebanon, 6752 pp. (in Arabic).

Al Suyuti (1445–1505) (1971). *Kashf al-salsala ʿan wasf al-Zalzala*, Ed. Abd al Latif Saadani, Fez, Morocco (in Arabic).

Al Tabari (839–923) (1967). *Ta'rikh al-rusul wa'l-mulûk*, tome 9, Ed. Dar al Ma'arif, Cairo, Egypt, 212 (in Arabic).

Ibn Al Adhari (1241–1295) (1948). « Kitāb al-bayān al-mughrib fī ākhbār mulūk al-andalus wa'l-maghrib », in *History of North Africa*, 2 vols. (VII–317 pp.), Ed. E. J. Brill, Leiden, The Netherlands, 301 pp. (in Arabic).

Ibn Al Athîr (1160–1233) (1872). *"al-kâmil fî al-târikh"*, 12 vols., Ed. Tomberg, Leiden, The Netherlands (in Arabic).

Ibn al Jawzi (1116–1200) (1987). *"al-muntadhem fi tarikh al umam wal muluk"*, tome XI, Ed. Dar al –Kutub Al-Ilmia, Beirut, Lebanon, 372 pp. (in Arabic).

Ibn al Jawzi (1116–1200) (1997). *Talkih fouhoum Ahl Al Ater fi aouioun eterikh et sier*, Ed. Wadi Al Arkam, Beirut, Lebanon, 63 pp. (in Arabic).

Ibn Taghribirdi (1411–1470) (1963). *Al-Nujum ʿal-zahirah fi muluk Misr wa-'al-Qahirah*, 16 vols., Ed. Dar Al-Kitab Al-Masriya, Cairo, Egypt (in Arabic).

Recent references

Ambraseys, N. N. (1962). The seismicity of Tunis, *Ann. Geofisc.* **XV,** no. 1, 233–244.

Ambraseys, N. N. (2009). *Earthquakes in the Mediterranean and Middle East: A Multidisciplinary Study of Seismicity up to 1900*, Cambridge University Press, Cambridge, United Kingdom, 947 pp.

Bahrouni, N., S. Bouaziz, A. Soumaya, N. Ben Ayed, K. Attafi, Y. Houla, A. El Ghali, and N. Rebai (2014). Neotectonic and seismotectonic investigation of seismically active regions in Tunisia: A multidisciplinary approach, *J. Seismol.* **18,** 2, doi: 10.1007/s10950-013-9395-y.

El Mrabet, T. (2005). *The Great Earthquakes in the Maghreb Region and Their Consequences on Man and Environment*, CNRST-LAG, Rabat, Morocco, 424 pp.

Farr, T. G., and M. Kobrick (2000). Shuttle Radar Topography Mission produces a wealth of data, *Eos Trans. AGU* **81,** 583–585.

Golvin, L. (1968). Quelques réflexions sur la grande mosquée de Kairouan à la période des Aghlabides, *Revue de l'Occident musulman et de la Méditerranée* **5,** 69–77 (in French).

Guidoboni, E., A. Comastri, and G. Traina (1994). *Catalogue of Ancient Earthquakes in the Mediterranean Area up to the 10th Century*, Istituto Nazionale de Geofisica, Rome, Italy, 504 pp.

Hfaiedh, M., and M. Allouche (1993). *Seismic Hazard in Tunisia, the Practice of Seismic Earthquake Hazard Assessment*, Diane Publishing Company, Collingdale, Pennsylvania, 244–249.

Hinzen, K.-G., C. Fleischer, S. K. Reamer, S. Schreiber, S. Schütte, and B. Yerli (2011). Quantitative methods in archaeoseismology, *Quaternary Int.* **242,** 31–41.

Kharrat, S., A. Harbi, M. Meghraoui, and S. Bouaziz (2018). The Tunisian homogenized macroseismic database (second century–1981): First investigations, *Seismol. Res. Lett.* **90,** no. 1, 347–357, doi: 10.1785/0220180237.

Laporte, J. P. (2015). D'Hadrumète à Sousse, des années 350 à 859. RM2E, *Revue de la mediterranée*, Ed. Électronique, Tome **II-1,** 3–34 (in Corsican).

Lichtenstädter, I. (1939). Muhammad Ibn Habib and his Kitab al-Muhabbar, *J. Roy. Asiat. Soc.* Part I, 27 pp.

Mahfoudh, F., S. Baccouch, and B. Yazidi (2004). *L'histoire de l'eau et des installations hydrauliques dans le bassin de Kairouan*, Ed. International Water Management Institute, Tunis, Tunisia, 82 pp. (in French).

Meghraoui, M., and S. Pondrelli (2012). Active faulting and transpression tectonics along the plate boundary in North Africa, *Ann. Geophys.* **55,** no. 5, doi: 10.4401/ag-4970.

Solignac, M. (1952). *Recherches sur les installations hydrauliques de Kairouan et des basses steppes tunisiennes du VIe au XIe siècle*, A.I.E.O., Alger, Algeria, 1–273 (in French).

Stiros, S., and R. E. Jones (1996). *Archaeoseismology (Fitch Laboratory Occasional Paper)*, British School at Athens, Athens, Greece, 268 pp.

Taher, M. A. (1979). Corpus des textes arabes relatifs aux tremblements de terre et autres catastrophes naturelles, de la conquète arabe au XII H/XVIII JC, *LLD Thesis*, University Paris I-Sorbonne (in French).

Vogt, J. (1993). Further research on the historical seismicity of Tunisia, *Terra Nova* **5,** 475–476.

Wessel, P., and H.F. Smith (1998). New, improved version of the generic mapping tools released, *EOS Trans. AGU* **79,** 579.

Younes, K. (2009). Akhbar El Zalazel fel Maghreb El Arabi (Reports on earthquakes in the Maghreb), *Revue de l'université islamique* Tome **13,** no. 1, 67–92 (in Arabic).

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