Is the Seismic Hazard in Tunisia Underestimated? An Archaeoseismological Study

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Abstract

The recent seismicity of Tunisia is considered sparse and moderate. A number of historical studies are available, but the archaeological evidence has not been properly used. Pilot studies were carried out at three sites in the less seismic middle part of Tunisia: Roman Thysdrus (Arabic El-Jem), and the Islamic *medina* (old town) of El-Jem, Sousse and Monastir. A selection of earthquake archaeological effects observed is shown (dropped keystones, fractured or extruded masonry blocks, columns displaced from plinth), marking the potential minimum intensity of shaking. To create this level of damage, local intensity IX is hypothesized. This is certainly higher than the 2007 seismic hazard map produced by WHO, where only medium intensities are indicated for the region. It is suggested that a systematic archaeoseismological study of Tunisia will contribute in improving seismic hazard assessment.

Keywords

Archaeoseismology • Earthquake • Seismic hazard • Tunisia

1 Introduction

The recent seismicity of Tunisia is considered sparse and moderate, mostly based on instrumental data. A number of historical studies are available. Utilizing the information hidden in archaeological objects has started only recently: Bahrouni et al. (2019) offered a glimpse in their studies on the archaeological evidence of the AD 859 earthquake in Kairouan.

Recently, the author carried out pilot studies in three sites in the less seismic middle part of Tunisia: Roman Thysdrus (Arabic El-Jem), and the Islamic *medina* (old town) of El-Jem, Sousse and Monastir. Short list of observed earthquake's archaeological effects is shown below, marking the potential minimum intensity of shaking (after Rodriguez-Pascua et al. 2011).

2 Methods

Sites were documented by visual observation, photography, and hand drawings. Measurements were taken by a Laser Disto 8 range finder, which allowed quick measuring of horizontal and vertical distances. Observed damage must be interpreted within the context of the building. Work on the details of the history of construction, destruction, and restoration of each site by literature studies is in progress.

3 Results

3.1 El-Jem, Roman Amphitheatre

- Dropped keystones—VII—frequent in radial arches, rare in tangential arches
- Dropped arch sectors (Fig. 1a)—VII. This is the highest, 'severe' damage category of arches, as understood by Hinzen et al. (2016).
- Collapsed arches/vaults—IX
- Extruded blocks (Fig. 1b)—IX(?)
- Penetrating fracture in arch masonry (Fig. 1c)—parallel to stress—VII. 'Severe' damage category of Hinzen et al. (2016).

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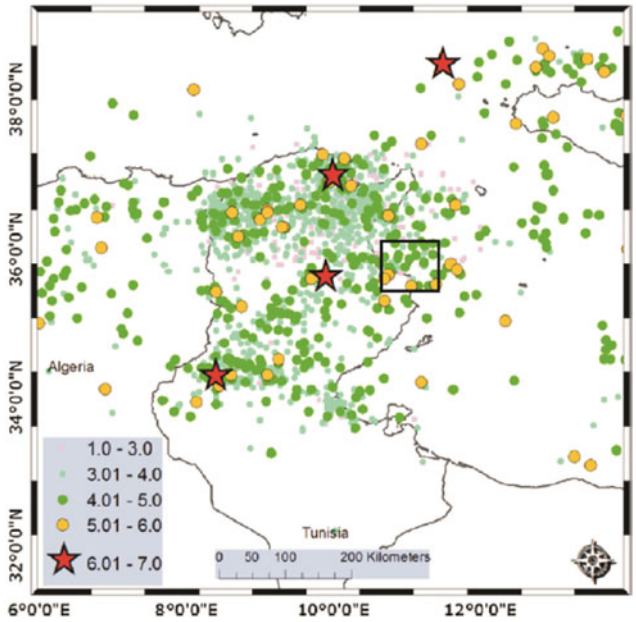

Fig. 1 Seismicity of Tunisia (after Ksentini and Romdhane 2014, modified). Sites in El-Jem, Sousse, and Monastir are within the rectangle. This is where a possibly $M > 6.0$ earthquake occurred within the last millennium, additionally to the already known three marked by stars

3.2 Sousse, Ribat and Kasbah (Islamic)

- Twisted walls (Fig. 2f)—VIII
- Broken corners of columns: axial and oblique (Fig. 1d)—VII
- Shift between column and capital (Fig. 2e)—IX
- Penetrating fracture through capital or plinth (Fig. 1d)—VII
- Extruded masonry block (Fig. 2g)—IX(?)
- Displaced arch sector (fallen keystone) (Fig. 2h)—VII
- Axial fracture in tower
- Column displaced from plinth—IX.

3.3 Monastir, Ribat (Islamic)

- Column displaced from plinth—IX
- Broken corners of columns: axial and oblique—VII.

4 Discussion and Conclusion

The current instrumentally recorded seismic activity nearby Sousse produced up to M 4.5 earthquakes (Bahrouni et al. 2014). Historical M 6–7 earthquakes are known in Tunisia (Ksentini and Romdhane 2014). However, their epicentres are more than 200 km away from Sousse: These probably did not cause major damage in public buildings and nearby the city. The archaeoseismic damage outlined above was certainly caused by at least one other major earthquake nearby, during the past millennium. It is suggested that a systematic archaeoseismological survey of Tunisia will change our perception of the seismic hazard of the country.

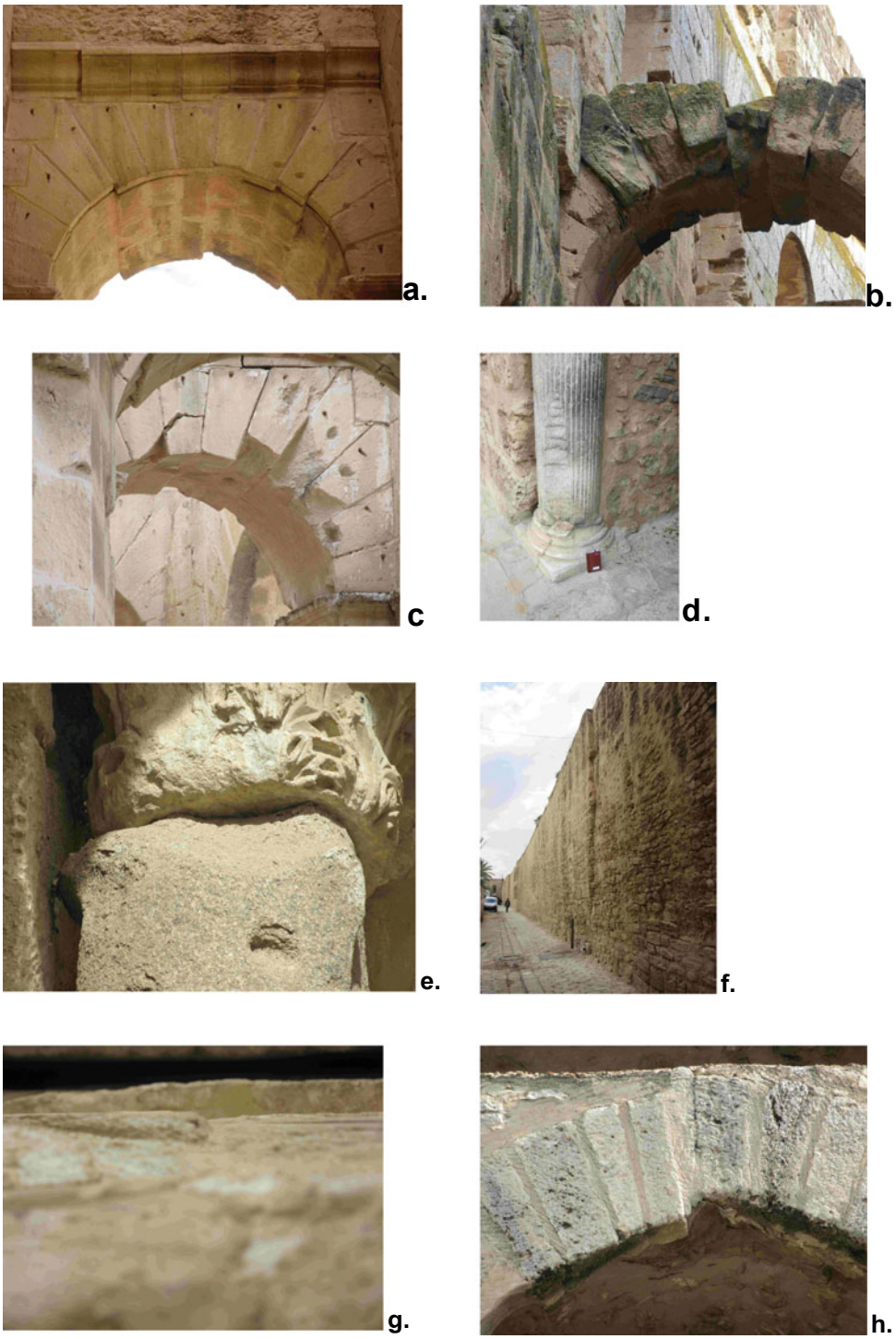

Fig. 2 Archaeoseismological evidence for damaging earthquakes in the middle part of Tunisia. **a** Dropped arch sectors. El-Djem amphitheatre. #6085. **b** Extruded blocks. El-Djem amphitheatre. #6062. **c** Penetrating fracture in arch masonry—parallel to stress. El-Djem amphitheatre. #6098. **d** Broken corners of columns: axial and oblique. Sousse, Ribat. #5794. Serial numbers refer to images in the archaeoseismological database (Moro and Kázmér 2019). **e** Shift between column and capital. Sousse, Ribat. #5800. **f** Twisted walls. Sousse. #5897. **g** Extruded masonry block. Sousse. #5805. **h** Displaced arch sector (fallen keystone). Sousse. #5867

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