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Earthquake damage history in Israel and its close surrounding - evaluation of spatial and temporal patterns

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ABSTRACT

Israel was hit by destructive earthquakes many times in the course of history. To properly understand the hazard and support effective preparedness towards future earthquakes, we examined the spatial and temporal distribution of the resulted damage. We described in detail our systematic approach to searching the available literature, collecting the data and screening the authenticity of that information. We used GIS (Geographic Information System) to map and evaluate the distribution of the damage and to search for recurring patterns. Overall, it is found that 186 localities were hit, 54 of them at least twice. We also found that Israel was affected by 4, 17, 8 and 2 damaging earthquakes that originated, respectively, from the southern, central, central-northern and northern parts of the Dead Sea Transform (DST). The temporal appearance of the northern earthquakes is clustered; the central earthquakes are more regular in time, whereas no damage from the north-central and the central quakes, with the exception of the year 363 earthquake, seems to have occurred south of the Dead Sea region. Analyzing the distribution of the damage, we realized that the number of the damage reports reflects only half of the incidents that actually happened, attesting to incompleteness of the historical catalogue. Jerusalem is the most reported city with 14 entries, followed by Akko (Acre), Tiberias, Nablus and Tyre with 8, 7, 7 and 6 reports, respectively. In general, localities in the Galilee and north of it suffered more severely than localities in central Israel with the exception of Nablus and the localities along the coastal plain of Israel, most probably due to local site effects. For the sake of hazard management, these observations should be considered for future planning and risk mitigation.
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1. Introduction

Instrumental earthquake records for Israel have been available since the beginning of the 20th century, during which this area was affected by the destructive M = 6.2, 1927 Jericho earthquake (e.g., Ben-Menahem et al., 1976; Vered and Striem, 1977; Avni, 1999) and the nearby M = 7.1, 1995 Nuweiba earthquake (Baer et al., 2008; Shamir, 1996). Obviously, these two instrumentally recorded earthquakes are neither sufficient to characterize the long-term impact of strong earthquakes nor to define typical spatial and temporal patterns of damage, if there are any. Thus, the historical records as well as archaeological and paleo-seismological evidence of pre-instrumental earthquakes may assist greatly in filling that gap.

Written in various languages from many places, historical damage reports include accounts, chronicles, drawings, manuscripts and, from the second half of the 19th century, also photographs (Zohar et al., 2014). Most of the reports were already collected, translated and organized within modern catalogues (e.g., Guidoboni et al., 1994; Guidoboni and Comastri, 2005; Sbeinati et al., 2005; Ambraseys, 2009), reappraisals (Karcz, 1987; Ambraseys and Finkel, 1995; Ambraseys and White, 1997; Ambraseys, 2004; Salamon et al., 2007, 2011; Salamon, 2009; Agnon, 2014; Marco and Klinger, 2014) and focused investigations (e.g., Ambraseys and Melville, 1988; Ambraseys and Barazangi, 1989; Ambraseys and Karcz, 1992; Ambraseys, 1997). Although some of these records contain inaccuracies and exaggerations (Karcz and Lom, 1987), they are still the richest sources available for resolving source parameters of earthquakes such as size and location, comparing earthquakes from different places and times and relating the past to modern earthquakes (e.g., Sirovich and Pettenati, 2001; Bakun et al., 2002, 2003; Sirovich and Pattenati, 2003, 2009; Bakun, 2006; Gasperini et al., 2010; Hough and Avni, 2010; Zohar and Marco, 2012).

Given the wealth of the existing data and the essential need of Israel to establish a reliable and up-to-date database of earthquake-related damage, we first reappraised the list of historical earthquakes that affected Israel and its close surroundings (Zohar et al., 2016). This task is now complemented with the construction of a focused, dedicated archive of the damage caused by these earthquakes, targeting first on compiling the inventory of reliable reports of damage and then analyzing the spatial and temporal spread of the damage in order to identify typical patterns if exist.

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2. The area of interest

We focused on the area of Israel and its close surroundings (Fig. 1) in attempt to delineate the typical scope of damage that may hit Israel, regardless of its tectonic origin. The main seismogenic fault in the study area is the Dead Sea Transform (DST) system (Fig. 1), that appears to cause the majority of the strong and damaging earthquakes in Israel (Ben-Menahem, 1991; Begin, 2005; Hamiel et al., 2009; Agnon et al., 2010). It is a left lateral fault system extending from the Red Sea in the south to southeastern Turkey in the north, and bordering the eastern side of the Arabian tectonic plate and the western side of the Sinai sub-plate. The overall sinistral displacement along the DST since its origin in the Miocene is estimated to ca. 105 km (e.g., Quennel, 1959; Freund et al., 1968; Garfunkel et al., 1981). That is, an average slip rate

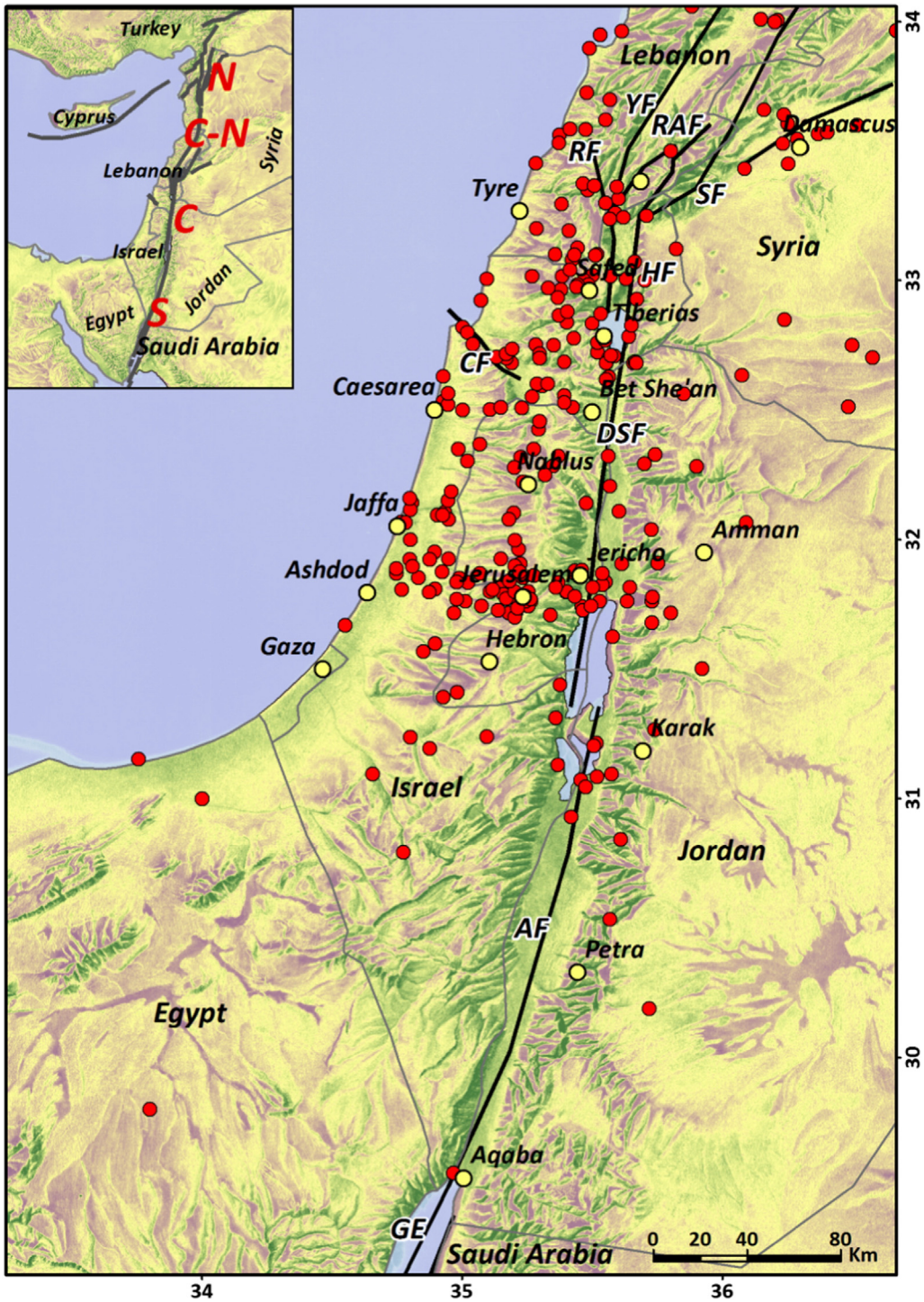

Fig. 1. Map of the study area and the localities that were hit during the last 2000 years (red circles). Yellow circles symbolize localities under focus in this study for being repeatedly hit. The main active tectonic element in that area is the Dead Sea Transform (DST) system. It is divided herein to three geographic parts (inset map): South (S), Center (C) and North (N), and the transition zone Center-North (C-N). The associated DST elements, from south to north, are: GE - the pull-apart structures in the Gulf of Eilat and Aqaba (Garfunkel and Ben-Avraham, 1996); AF – Arava Fault (Amit et al., 1999; Zilberman et al., 2005; Porat et al., 2009); DSF – Dead Sea Fault (Garfunkel et al., 1981); CF – Carmel Fault; HF – Hula Fault; RF – Roum Fault (Khair, 2001; Nemer and Meghraoui, 2006); YF – Yammouneh Fault (Daëron et al., 2007); RAF – Rachaya Fault (Nemer et al., 2008); SF – Sergaya Fault (Nemer et al., 2008). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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