Map of the main seismic sources of Israel: explanation pages

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This map was edited based on geological and seismological synthesis of fault activity in Israel region (Sharon, 2019), and on recent direct GPS measurements of specific fault traces (Sadeh et al., 2012, Masson et al, 2015, Hamiel et al., 2016, 2018a,b,).

The main seismic sources are faults and fault zones that are likely to generate significant (> 6) earthquakes in Israel. The only two instrumentally recorded significant earthquakes are the 1995 7.2 M_W Nuweiba earthquake occurred on the Aragonese Fault which was associated with mean slip of 1.4–3 m (Baer et al., 1999), and the 1927 6.25 M_L Dead Sea earthquake (Shapira et al. 1993), which result in hundreds casualties and a severe damage. All other information is based on geodetic, geologic, prehistoric and historic evidences (e.g. Sadeh et al., 2012; Klinger et al., 2015; Zohar et al., 2016). The faults constitute potential sources for earthquakes that can cause different sorts of damages, including ground motion and acceleration, landslides, liquefactions, surface rupture and tsunamis. The map is essential for seismotectonic modelling of Israel, probabilistic seismic hazard analysis (PSHA) and eventually for generating ground motion maps. The mapped faults are also important for establishments of standards, such as Israeli standard SI 1227 for bridges. The traces of most of the faults in the map are located and mapped using 1:50,000 geological maps of Israel of the geological survey of Israel. Fault beyond the Israeli borders, inferred subsurface fault continuations, and inferred submarine faults are mapped based on the references listed in table 1. We note that the certainty in the locations and even in the existence of some of the inferred faults can be low and should be better constrained in the future. We also note that large earthquakes along the Cyprian Arc can generate tsunamis that might affect the coastline of Israel (Salamon et al., 2000). This source is not analysed and mapped here, but should be taken into account in regional seismotectonic models.

Table 1: used references for faults beyond the Israeli borders and inferred faults

Geographic area	Reference
Gulf of Elat*	Ben-Avraham, 1985; Hartman et al., 2014;
Arava valley#	Calvo, 2002; Le Béon et al., 2012; Sneh and Weinberger, 2014
Dead Sea basin*$#	Ben-Avraham and Schubert, 2006; Sneh and Weinberger, 2014
Jordan valley (east to Jordan River)#	Ferry et al., 2007; Sneh and Weinberger, 2014
Gilboa fault (western part)$	Sneh and Weinberger, 2014
Carmel fault (eastern part) $	Sneh and Weinberger, 2014
Carmel fault (western part) *	Schattner and Ben-Avraham, 2007
Hula basin#$	Schattner and Weinberger, 2008
Lebanon and Syria#	Weinberger et al., 2009; Garfunkel, 2014; Sneh and Weinberger, 2014

*Submarine inferred faults
Faults beyond the Israeli borders
$ Subsurface inferred continuations of the main faults

Below, two subgroups of faults are defined by their tectonic characteristics, geometries and their slip rates. For further discussion on the selection of segments for this subgroup see Sharon et al., (2018).

Main strike-slip segments of the Dead Sea Fault

This category (solid black in the map) includes potential sources for Large to Major earthquakes in the Israel region. Our database include fault segments from this subgroup, which are located up to 200 km away from the northern Israeli borders and 100 km from the southern border. Previous analyses of maximum earthquake magnitude based on historical earthquakes or on background seismicity predicted magnitudes of ≤ 7.8 M_w for the largest segments of the DSF (e.g., Stevens and Avouac., 2017; Klinger et al., 2015; Hamiel et al., 2018a). According to paleoseismic and/or geodetic investigations (Table 1), these faults are associated with Holocene slip rates of 1 mm/yr < V_{Si} < 5 mm/yr, where V_{Si} is the average sinistral slip component accommodated by these faults. Equally important, all the faults in this category are relatively long with a preferable slip orientation according to the present stress field (Eyal and Reches, 1983).

South to Lebanon, geodetic measurements show ~ 4–5 mm/yr sinistral slip (Hamiel et al., 2016; 2018a; 2018b; Masson, 2015). Along the Dead Sea fault valleys (Jordan river valley, Dead Sea basin, and Arava valley), the location and slip rates of fault segments from this subgroup are continuously mapped and measured, while the exact fault locations along the Gulf of Eilat-Aqaba is less known.

Faulting in Lebanon is partitioned to a few branches and the specific rates are less constrained. While the Yammuneh and the Serghaya faults can undoubtedly be considered as independent sources for significant earthquakes, the status of the shorter, Rachaiya and Roum fault branches are less clear. Nevertheless, according to the present state of information (see for example, Nemer and Meghraoui (2006)), we cannot rule them out and they remain part of this subgroup.

Table 2: Main strike-slip segments of the Dead Sea Fault: slip rate details

Fault	**Strike-slip rate [mm/yr]**	**Data**	**Period**	**Reference**
Aragonese [ARF]	~5*	GPS	Recent	Baer et al. 1999; Hamiel et al., 2018a
Arava [AF]	~4.9#	GPS	Recent	Masson et al., 2015
Evrona [EF]	5.0±0.8#	GPS	Recent	Hamiel et al., 2018a
Jericho [JF]	4.8±0.6#!	GPS	Recent	Hamiel et al., 2018b
Jordan Valley [JVF] (central)	~5#	Geology	~25ka	Ferry et al., 2011
Jordan Valley (South to Sea of Galilee)	4.1±0.6#&	GPS	Recent	Hamiel et al., 2016
Jordan Gorge	4.1±0.6# ~3# ~2.6#	GPS Geology Archaeology	Recent ~5ka ~3ka	Hamiel et al., 2016 Marco et al., 2005 Ellenblum et al., 2015
Lebanon Restraining Bend (LRB)	3.8±0.3*	GPS	Recent	Gomez et al., 2007
Qiryat Shemona	3.9±0.3*!	GPS	Recent	Gomez et al., 2007
Roum	0.86–1.05#	Geology	Holocene	Nemer and Meghraoui, 2006

Serghaya	1.4±0.2#	Geology	Holocene	Gomez et al., 2003
Yammuneh (LRB – northern part)	2.8±0.5	GPS	Recent	Gomez et al., 2003; 2007
Yammuneh (north of LRB)	6.9±0.1# 4.2±0.3*	Geology GPS	2ka Recent	Meghraoui et al., 2003 Gomez et al., 2007

Geodetic or geological measurements on a specific segment.
! 0.8 mm/yr of extension normal to the fault
* According to geodetic-based model
[&] Partially creeping

Main marginal faults and branches

This subgroup (pale blue lines in the map) consists of fault zones with lengths of several dozen kilometres that are associated with the DSF. It is assumed here, that these zones constitute a potential source for intermediate to strong earthquakes. The subgroup includes the Hazbaya Fault in Lebanon; the fault zone in the western and eastern margins of the Dead Sea; the marginal faults of the Hula basin; the Carmel Tirza fault zone (CTF) and the Elat Fault. The estimated slip rates of these fault zones are relatively low, (usually ≤ 1 mm/yr). The subgroup faults selected using recent associated seismic activity (Sharon, 2019), recent slip rates (table 3) and traces lengths (Stirling et al., 2002, 2013). The partitioning of the slip rate across parallel segments in any given zone is usually below the geodetic measurement (or the information) resolution. Therefore, the segments of this category are representative, but not necessarily the most active within a given system. In addition, the faults of this group might rupture as part of a major earthquake on the main strike-slip segments of the Dead Sea Fault.

Table 3. Marginal faults and branches: slip rate details

Fault	Slip rate [mm/yr]	Data	Period	Reference
Dead Sea basin marginal faults	≥1 Based on basin subsidence rates	Geology Geophysics	Pleistocene-Holocene	Torfstein et al., 2009; ten Brink and Flores, 2012; Bartov and Sagy, 2004

Carmel Fault Carmel Fault	total slip rate 0.9±0.45 (0.7±0.45 lateral; 0.6±0.45 extension) < 0.5	GPS Geology	Recent 200ka	Sadeh et al., 2012 Zilberman et al., 2011
Hula western border	> 0.4 Based on basin subsidence rates	Geology Geophysics	~1 Ma	Schattner and Weinberger, 2008
Elat	<1 Based on Holocene and Pleistocene units relationship	Geology	Holocene	Amit et al., 2002; Porat et al., 1996; Shaked et al., 2004

Due to the lack of reliable historical and paleo-seismological evidences, the evaluation of maximum possible magnitude on these faults (distinct from mega events associated with the first subgroup) is usually very speculative. Here we evaluate, based on segment lengths and slip rates, that they constitute a potential for intermediate earthquake (magnitude 6–6.5).

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