

Short notice on earthquake hazard in Lebanon

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1- Geological setting: the plate boundaries.

Lebanon, like all other countries, is bound to its geological reality. Lebanon is sitting astride an active plate boundary, known as the Levant Fault System (also known as the Dead Sea Transform), where the Arabian plate to the east is sliding northward and counterclockwise relative to the Sinai plate to the west.

Lebanon also faces another major plate boundary to the west, over the Cyprus area in the Eastern Mediterranean, where the Sinai plate is being pushed under the Anatolian plate. The corresponding fault system is known as the Cyprus subduction zone.

Lebanon is caught between all these active areas (Fig1). The relative motion of these plates makes it inevitable that earthquakes happen in the region. Well documented historical, large seismic events are known to have happened here (Fig2), and others are expected to happen again in the future.

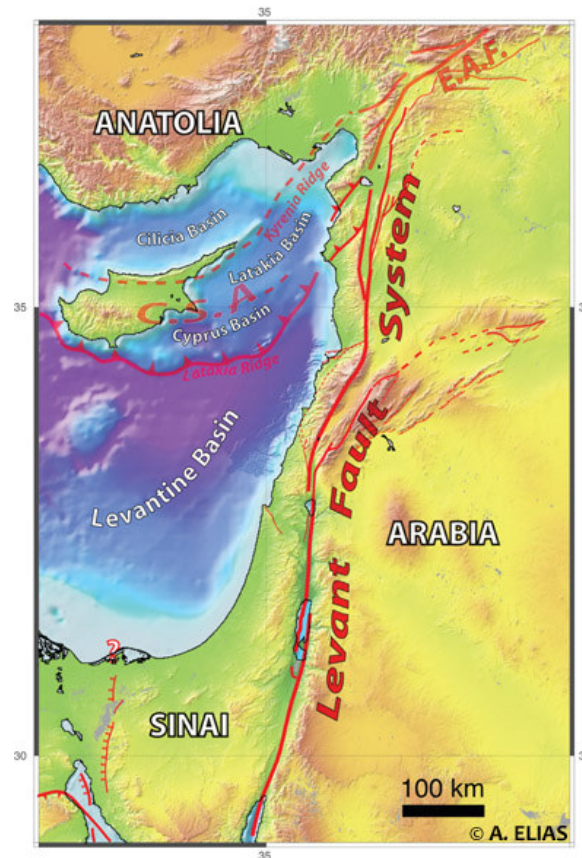


Figure 1: Map showing the major tectonic plate boundaries and fault lines in the Eastern Mediterranean.

2- The local faults:

Three major fault lines cut the country (Fig3). They represent the Lebanese part of the Levant Fault System, as they connect the southern faults in Palestine and Jordan with their Northern counterparts in Syria. These three segments are the most likely places for large earthquakes (Magnitude greater than 7) to happen (Fig2). The Serghaya Fault, the easternmost, is running parallel to the borderline with the Syrian Arab Republic. The central and most prominent one is called the Yammounh Fault. It runs along the eastern flank of Mount-Lebanon, over the

entire length and almost in the middle of the country. The third fault called the Mount-Lebanon Thrust is mainly offshore, and runs under the entire western flank and coast of Mount-Lebanon. Because it is in large parts underwater, the earthquakes produced by this last fault line can generate tsunami.

Other smaller faults occur in Lebanon. These can generate earthquakes of magnitude up to 6-6.5.

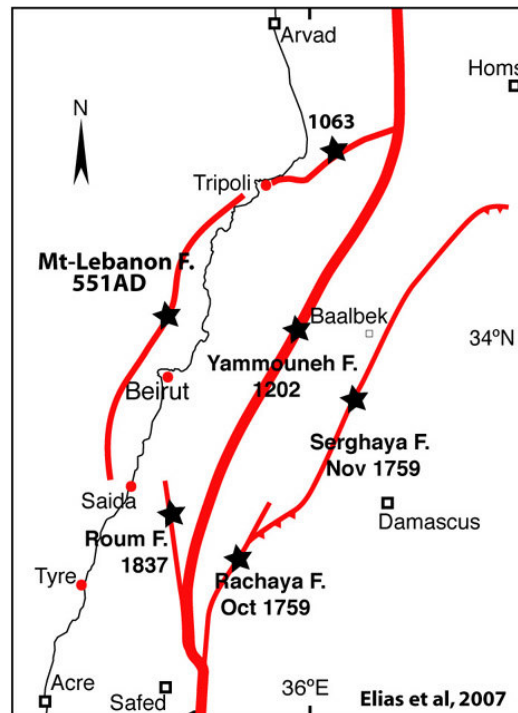


Figure 2: Map of the location of major known historical earthquakes in association with the major active faults in Lebanon.

3- Earthquake activity and hazard:

Precise seismic monitoring in the country is unfortunately limited to the post 2006 period only. Location maps of recent earthquake show that small to moderate-size earthquakes can happen anywhere in this country.

A better understanding of the real earthquake hazard can be done using the wealth of information from historical records found in the archeological and the written records going back in time 2-3 kyrs. They show that the rate of earthquake activity is not high, and the frequency of large events is low.

Geological research showed that the large-size faults in this area produce earthquakes with magnitude >7 once every ~ 1000 yrs for the Yammouneh Fault, 1500-1750 yrs for the Mount-Lebanon Thrust, and ~ 2000 yrs for the Serghaya Fault. The small earthquakes are much more frequent and the country witnesses 1-3 earthquakes with $5 < M < 6$ every decade.

Research work on the activity of these faults has shown that two of the major faults are ready and in time, about to produce a major event. The Yammouneh fault did not produce major events since the year AD1202. The Mount-Lebanon Thrust last earthquake was in the year AD551.

A major earthquake on any of these two faults should not be a surprise.

On the other hand the Serghaya Fault has "recently" ruptured in the year 1759, and thus is unlikely to rupture again.

Considering the area on a larger scale, the 1927 Jericho earthquake and the 1995 Aqaba earthquake both on the southern segments of the Levant Fault System can be the signs that the entire Levant Fault System has entered a period of increasing seismic activity after a

dormancy of more than 8 centuries. Researchers from Israel, Palestine and Jordan also expect the fault to break "soon" in a series of major earthquakes.

To the hazard associated with the Levant Fault System one should also add the hazard represented by the Cyprus Subduction Zone to the west. This is a source of major earthquakes in the Eastern Mediterranean. Unfortunately very little studies and information are available to document its activity. But comparing with other subduction zones in the Mediterranean (Hellenic zone) and worldwide it is well known and established that these areas are capable of the largest earthquakes ($M > 8$), and are most likely to produce important tsunami waves.

Therefore the earthquake hazard in Lebanon is high.

Because the country is of small size compared with the important number and size of the active faults it hosts, potential earthquakes' locations can be considered as equally probable over the entire area.



Figure 3: Google-earth map showing the major active faults in Lebanon. Thickness of the lines denotes the importance of the fault line in terms of possible earthquake magnitude.

4- The associated hazards:

The intensity of the ground shaking from a moderate or major earthquake will affect large parts of the country. The hard rocky underground of the Lebanese geology will help attenuate

these accelerations. However the mountainous morphology and the deep valleys found over most of the country, with the occurrence of weak type of geological layers especially in the Daniyeh, Chouf and Metn areas, will increase secondary hazards such as slope instabilities, rockfalls or landslides. This can result in severe damage to bridges and roads.

Soil liquefaction is another major hazard in areas built over alluvial plains, especially in the coastal zone (Akkar, Tripoli, Batroun, Northern and Southern suburbs of Beirut, Damour, Saida , Tyre as well as in the Bekaa valley) that can result in severe damage to constructions and lifeline with special hazards related to critical infrastructure such as the Rafic El Hariri International Airport the seaports and the electrical power plants of Zouk, Zahrani and Deir Amar also vulnerable to tsunami hazard.

The small size of Lebanon makes it also prone to seismic hazard associated with nearby major faults from the surrounding countries.

Finally the bad infrastructure and the lack of any appropriate building seismic code or disaster management plans make the country risk profile very dangerous.