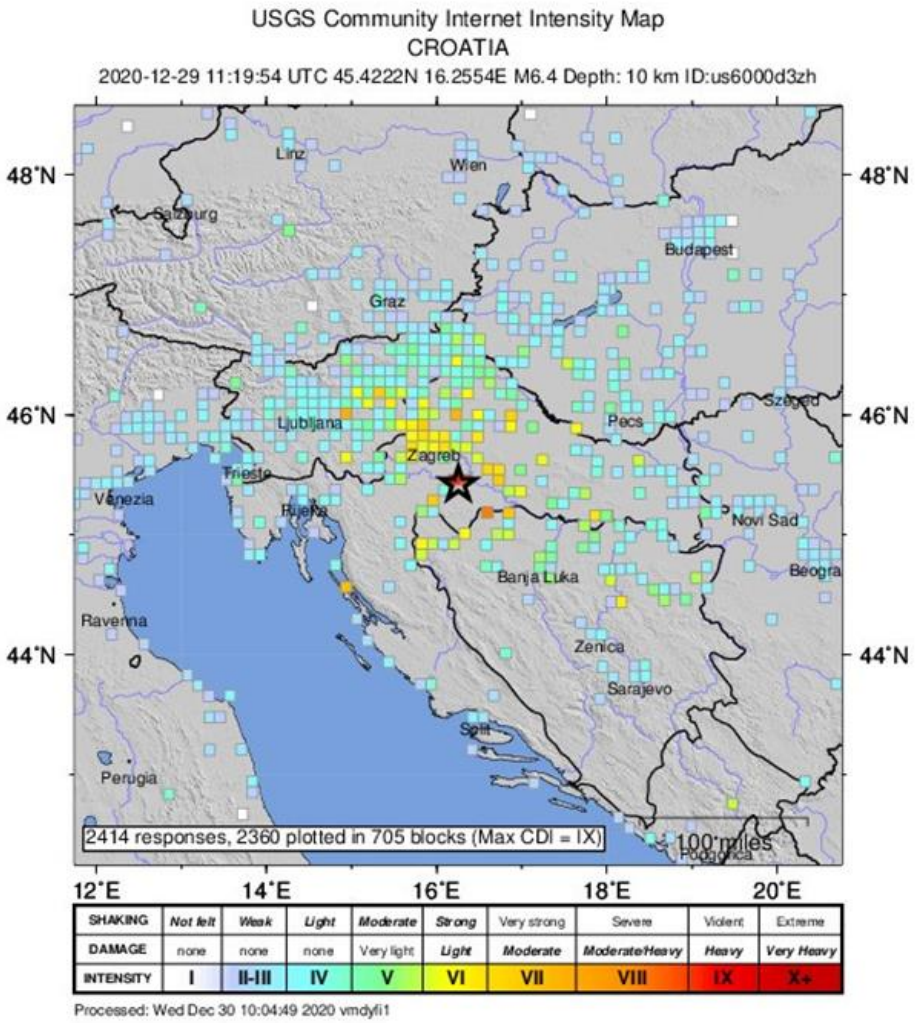
Earthquakes in Croatia in the year of the pandemic

Introduction

2020 was marked by two disasters in Croatia - the Covid-19 pandemic and severe earthquakes. The first “victim” was our capital, Zagreb, when the first case of Covid-19 was confirmed on February 25, 2020. Less than a month later, on March 22, Zagreb was hit by a big earthquake the magnitude of M = 5.5 on the Richter scale. Many greater and minor earthquakes followed with a death toll. At the same time, the pandemic was heading to a peak in the first wave.

After all these misfortunes, on December 29, 2020, and after many foreshocks, the areas of Sisak and Petrinja were hit by a massive earthquake the magnitude of 6.2 on the Richter scale, with the epicentre the southwest of Petrinja. In the following days, a total of 7 deaths were recorded, and since the very first records from 1909 in Croatia, this earthquake has been the biggest (until 2019, 1364 earthquakes had been recorded).

Picture 1 shows the intensity of the impact the earthquake had in different cities in Croatia and neighbouring countries - it is the second norm of the earthquake, in addition to the magnitude (intensity depends on the depth of the epicentre, while magnitude does not, so the earthquake of the same magnitude can be major or minor).

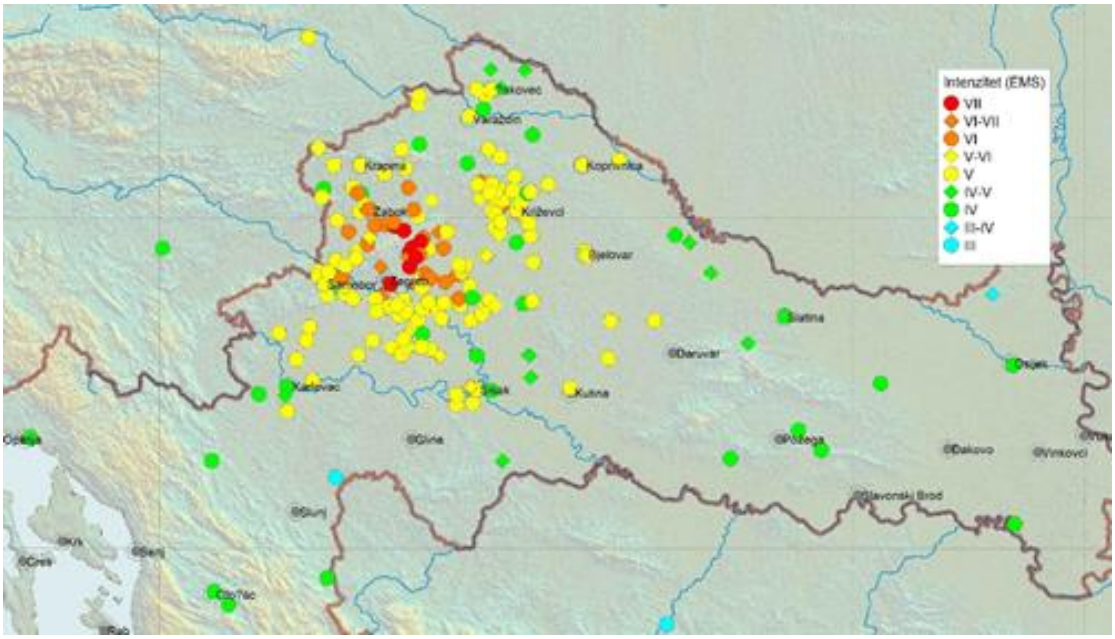


Picture 1. Earthquake intensity map generated according to citizen reports.
Source:*https://earthquake.usgs.gov/earthquakes/eventpage/us6000d3zh/dyfi/intensity*

Earthquakes in Zagreb

On March 22, 2020, at 6.24, Zagreb and its surroundings were hit by a great earthquake the magnitude of M = 5.5 on the Richter scale. The earthquake could not be predicted since it took only two seconds from the arrival of seismic waves from the epicentre to the centre of Zagreb (7 km). The seismic activity was most pronounced in the first days, and in the next 25 days, the ground shook 146 times. 27 people were hurt and one of them died. The city centre was hit the most. Much damage was reported to the cultural and historical heritage of the city of Zagreb, with serious damage to the south tower of the Cathedral. About

16,555 residential, public and monumental buildings were damaged. State institution buildings, sacred objects, museums, galleries, the Mirogoj Cemetery, the Rectorate, faculties, schools, and theatres also suffered a great amount of damage. The repair process has just started and it will take a long time.



Picture 2. Preliminary earthquake intensity map in Zagreb and surroundings (Source: https://www.pmf.unizg.hr/geof/seizmoloska_sluzba/o_zagrebackom_potresu_2020/pola_godine_od_potresa

Earthquakes are not uncommon in Croatia. They are often caused by the movement of the African tectonic plate toward the Eurasian, and this began 160 million years ago.

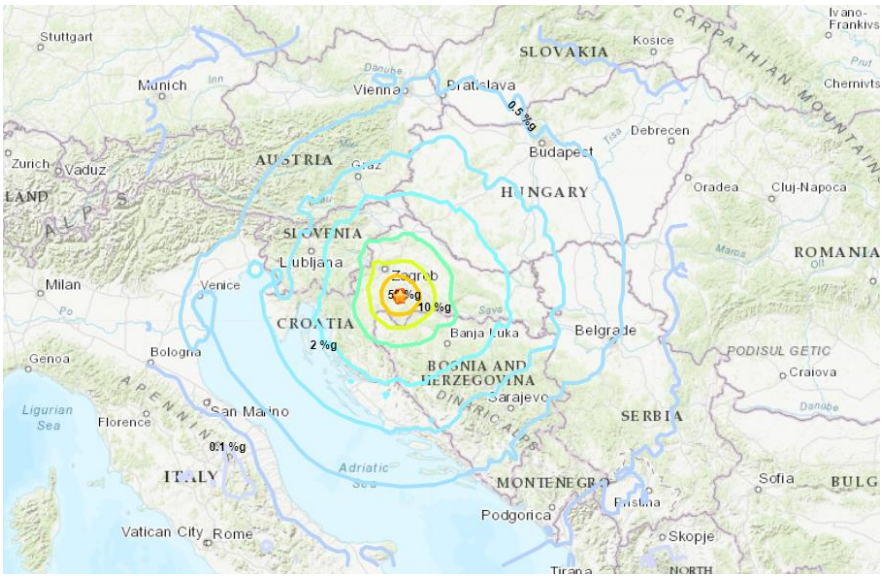
Earthquakes in Petrinja

Monday, December 28, 2020, marked the beginning of major disasters which can commensurate with those during the Homeland War in 1991. Banovina began to shake. At 6:28 the area of central Croatia was strongly hit by an earthquake of magnitude 5.0 on the Richter scale with the epicentre near Petrinja and was also

felt in neighbouring countries. That morning, two bigger earthquakes happened - the first at 7:49 (magnitude 4.7) and the second at 7:51 (4.1).

On Tuesday, December 29, 2020, Banovina was hit by a devastating earthquake the magnitude of 6.2.

The epicentral area of this earthquake is located in the zone of the above - mentioned tectonic contacts - "seams".



Picture 3. Map of ground surface vibration during the main earthquake in Petrinja (December 29, 2020; 12:19 min)
Source: *https://earthquake.usgs.gov/earthquakes/eventpage/us6000d3zh/map*

The Croatian government set up the Earthquake Elimination Headquarters, and the Croatian Centre for Earthquake Engineering started to inspect all buildings, marking them with red (unusable), orange (temporarily unusable) and green (usable) labels. In the meantime, people were accommodated in halls, tents, containers which were donated from many parts of Croatia or state commodity stocks, as well as donations of food and clothing. Unfortunately, many people had to sleep in cars - for many it was probably the only option. Food was initially prepared by volunteers, later by a state company Pleter. Many residents are afraid of what will happen to their homes and animals. They suffer major traumas.

From December 28, 2020, to January 28, 2021, 622 earthquakes of magnitude greater than 2.0 occurred in Petrinja.

A look at the history

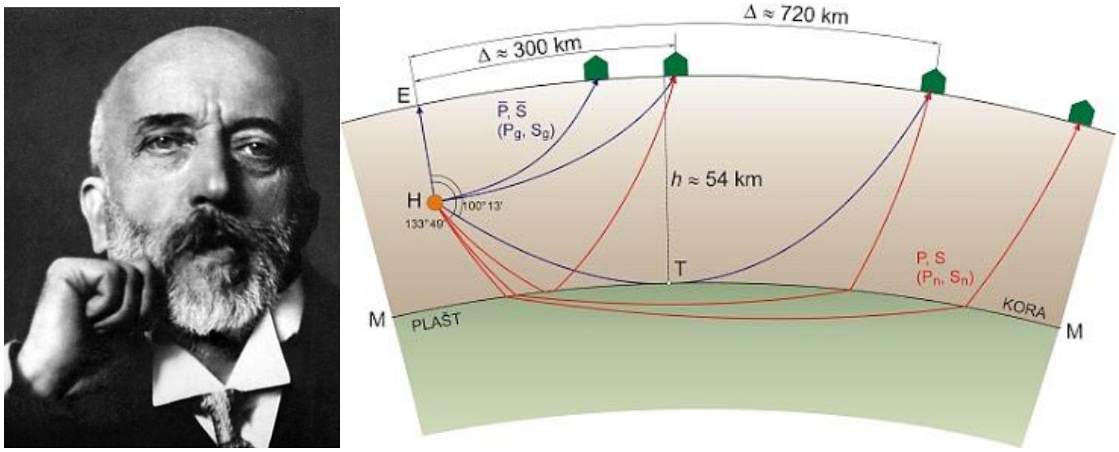
Date	Location	Magnitude	Intensity (°MCS)
April 6, 1667	Dubrovnik		IX-X
November 9, 1880	Zagreb		VIII
November 8, 1909	Pokuplje	5.8	VIII
March 12, 1916	Vinodol	5.8	VIII
March 27, 1938	Novigrad Podravski	5.6	VIII
December 29, 1942	Imotski	6.2	VIII-IX
January 11, 1962	Makarska	6.1	VIII-IX
April 13, 1964	Dilj Gora	5.7	VIII
September 5, 1996	Ston-Slano	6.0	VIII

Table 1: (personally created list based on the following article: https://www.pmf.unizg.hr/geof/seizmoloska_sluzba/seizmicnost_hrvatske)

On the morning of October 9, 1880, Zagreb was hit by a massive earthquake. The earthquake damaged and collapsed many buildings (almost all 3670 buildings were damaged, 12.6% were severely damaged) and three people were killed in the city of Zagreb.

On October 8, 1909, an area about 40 kilometres away from Zagreb was hit by a strong earthquake. The famous seismologist and geophysicist Andrija Mohorovičić dealt intensively with this great earthquake. Studying the records of this earthquake from various seismographs in Croatia and Europe, he noticed

that earthquake waves accelerate at a certain distance from the surface. He realized that also the density in these areas differs, that is, that the Earth is not homogeneous. He soon discovered the discontinuity between the earth's surface and the mantle, which is now called the Moho layer in his honour.



Picture 4: (Source: https://hr.wikipedia.org/wiki/Andrija_Mohorovi%C4%8Di%C4%87) , (http://www.gfz.hr/sobe/diskontinuitet.htm)

To sum up…

Earthquakes represent an unpredictable but very dangerous natural hazard that we cannot control. During these difficult times of the COVID-19 pandemic in which many countries are economically weakened, two strong earthquakes have occurred in Croatia, with a return period of 100 years or more. Although we cannot predict and prevent them, technology allows us to gain knowledge about the seismicity of the area in which we live. Moreover, projects and activities such as ERASMUS Help me! are a great opportunity for spreading a word and raising awareness about what we need to do and how to prepare in the future if we want to ensure a safe environment in our communities.

Sources

https://www.pmf.unizg.hr/geof/seizmoloska_sluzba/seizmicnost_hrvatske , (8.2.2021.)

https://www.pmf.unizg.hr/geof/popularizacija_geofizike/crtice_iz_povijesti#ZG1880 (8.2.2021.)

https://www.pmf.unizg.hr/geof/seizmoloska_sluzba/seizmicnost_hrvatske (8.2.2021.)

https://www.pmf.unizg.hr/geof/popularizacija_geofizike/crtice_iz_povijesti#ZG1880 (8.2.2021.)

https://www.mdpi.com/2076-3263/10/7/252/htm (8.2.2021.)

https://www.pmf.unizg.hr/geof/seizmoloska_sluzba/o_zagrebackom_potresu_2020/pola_godine_od_potresa (8.2.2021.)

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