**"SM3.1/NH4.12"** Session: Taking advantage of the exponential growth of data: toward a better assessment of ground-shaking, seismic hazard and seismic risk

# Contribution for seismic hazard assessment with local scale focus on Durrës (Albania) and damage observation after the ML 5.4, 21st September 2019 earthquake


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# Introduction

Surface geology is generally considered to influence the ground motion recorded on site.

The analysis of the influence of local effects on seismic response at ground surface appears relevant in densely populated cities. This is the case of  Durrës, in Albania, a fast developing city prone to high seismic risk and also characterized by several important archeological and cultural heritage sites.

Preliminary results obtained from recent geophysical in-situ measurements
and geological surveys, carried out in Durrës after the ML 5.4, 21$^{st}$ September 2019 event, are here presented with the aim of providing new elements for the assessment of local seismic hazard and following a comprehensive approach to the modifications induced by the site.

The activities are carried out within the framework of the CNR/MOES Joint research project “Seismic risk assessment in cultural heritage cities of Albania” in the biennium 2018-2019 (https://www.cnr.it/en/bilateral-agreements/agreement/60/moes-ministry-of-education-and-sport-of-the-republic-of-albania).

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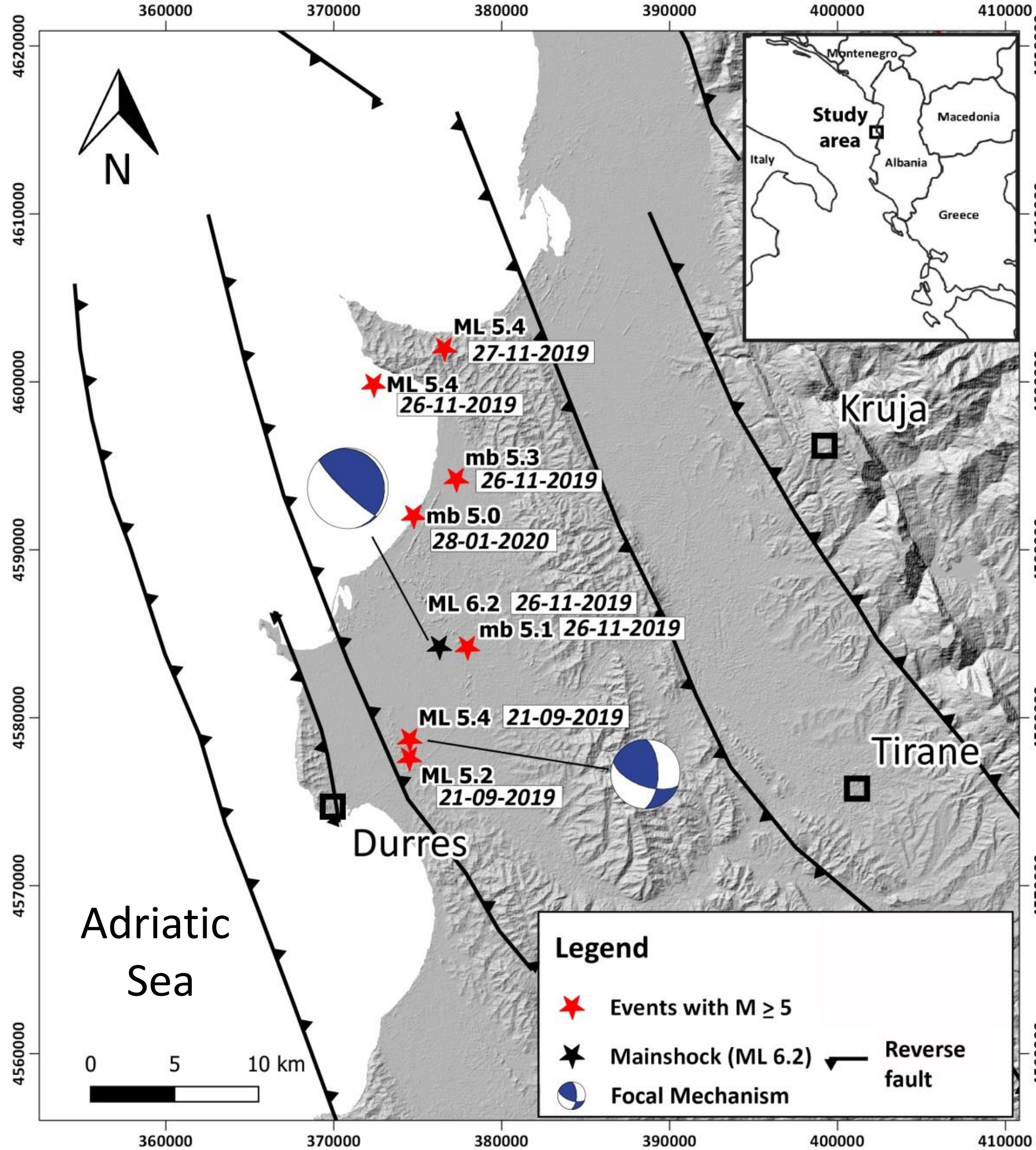
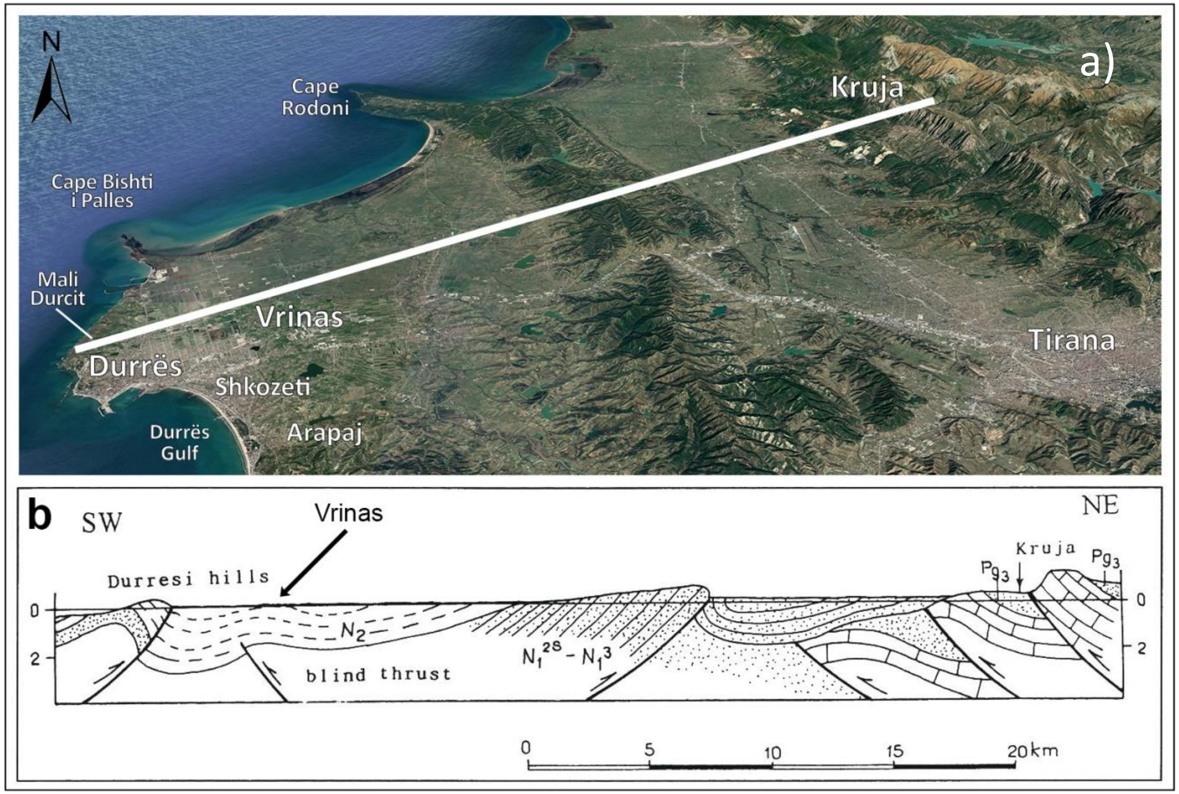
**The city of Durrës was recentely struck by a Mw 6.2 mainshock event** ([http://cnt.rm.ingv.it/](http://cnt.rm.ingv.it/)event/23487611) that caused considerable damage and 51 victims.

**The city is located on an actively seismo-tectonic belt**, the **Periadriatic Basin** in the western Albanides, where seismic catalogues report several past events with magnitude higher than 6.



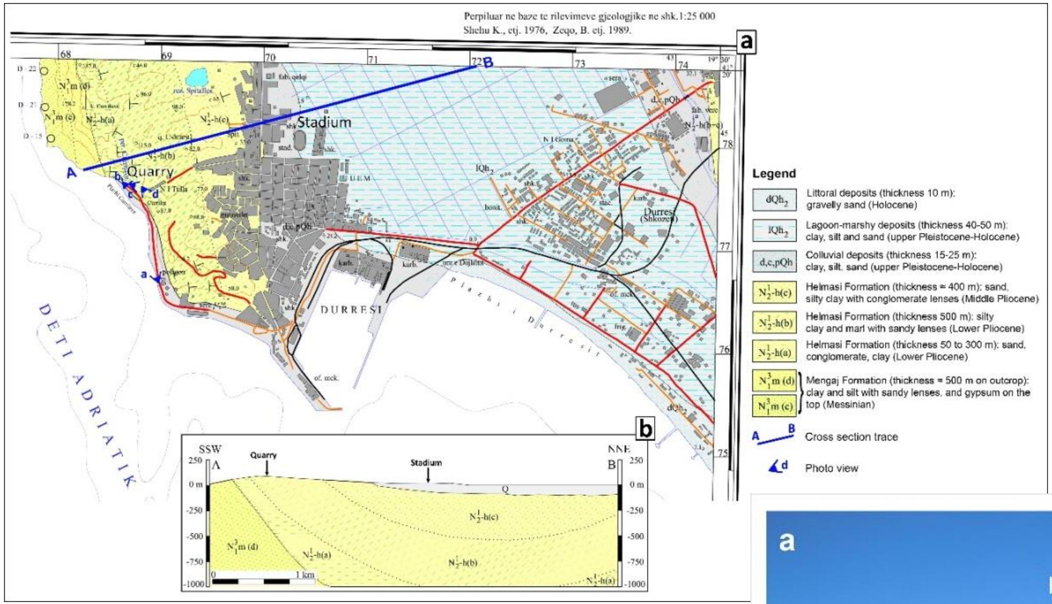

**Evolution of the 2019 Durrës earthquake sequence** , showing the location of all mainshocks of M ≥ 5.0 . Focal mechanisms are avilable at: cnt.rm.ingv.it, while active faults in the study area are available from the GEM - GAF (Global Active Faults) project catalogue (Weatherill et al., 2016).

# Geological and geomorphological setting



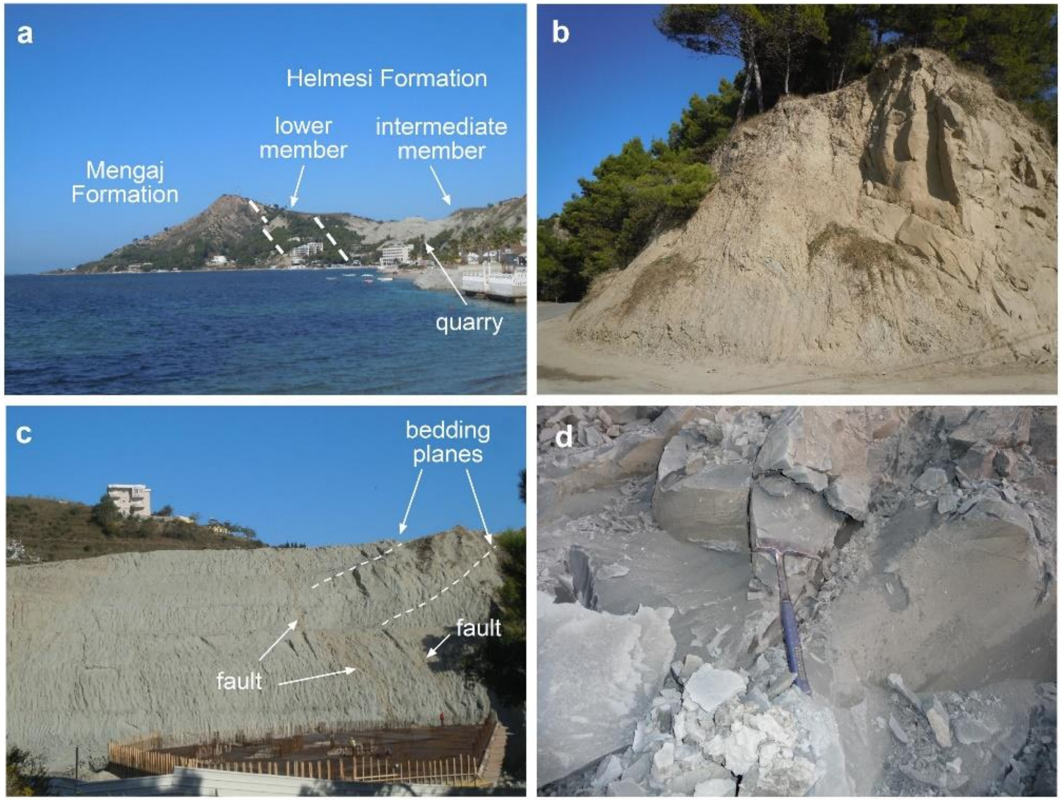

a) **Tridimensional view from south of the Durrës area** (image from Google Earth Image©2019TerraMetrics); b) **Cross section showing the structural setting of the Periadriatic basin** from Durrës to Kruja (Meço and Aliaj, 2000). Pg3: Oligocene siliciclastic turbidites (flysch) covering platform carbonates of the Kruja Nappe (brick pattern); N1: Serravallian-Messinian siliciclastic deposits (molasse); N2: Pliocene-Pleistocene terrigenous foredeep basin deposits.


Corographic map of the the Durrës area, showing a **wide marshy area** (Kënëta e Durrësit) **north of the town** reclaimed in the XX century (from Übersichtskarte von Mittel-Europa, 1914).




a) Sketch of the Geological Map of Albania (scale 1:25.000, Durrës Sheet)
b) SW-NE trending geological section crossing the city (modified after Kodra and Naçi, 2012).

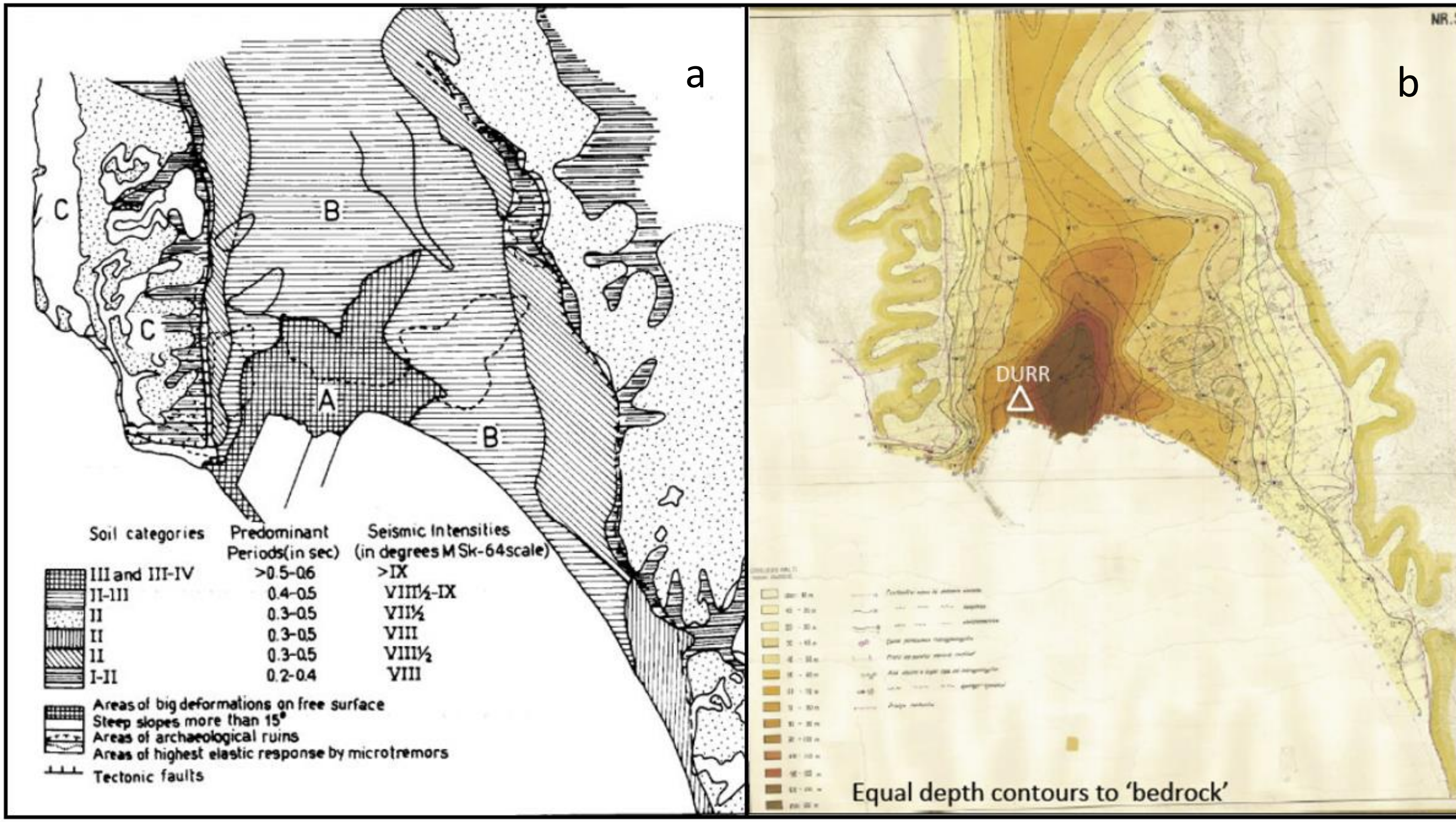
***(Geological bedrock in yellow*; *soft cover deposits in pale blue)***




**Geological bedrock of Durrës.**

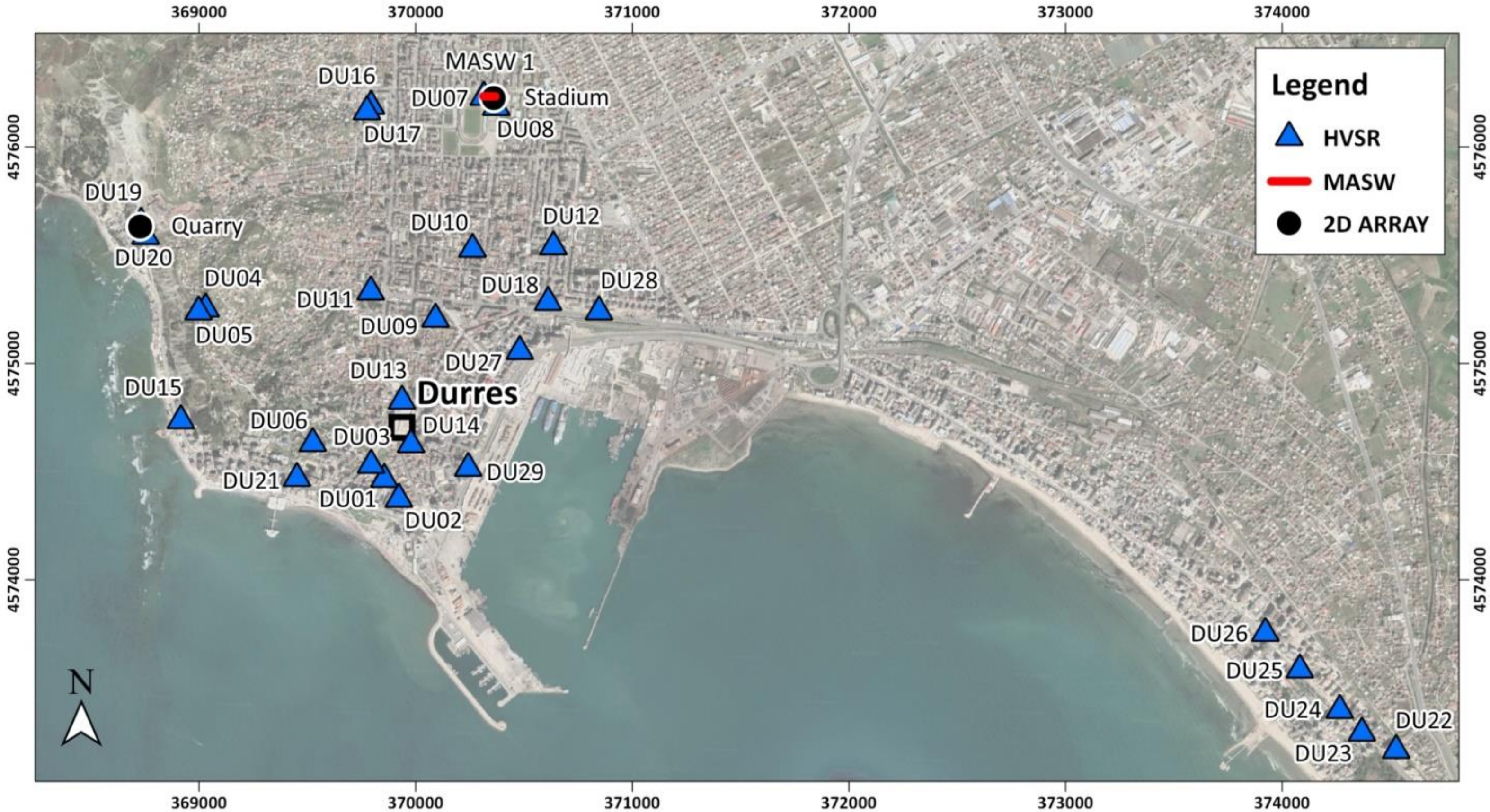
a) View of the Plazhi Currilave beach and the Mali i Durrësit ridge (187 m) from south, with the eastward tilted Maglaj and Helmasi Formations (Messinian and Lower Pliocene respectively).
b) Lower sandy-clayey member of the Helmasi Formation.
c) View from north-west of the NNE-SSW oriented quarry front (Helmasi Fm.
d) Strongly over-consolidated and jointed clays of the Helmasi Formation.

# Previous microzonation studies on Durrës



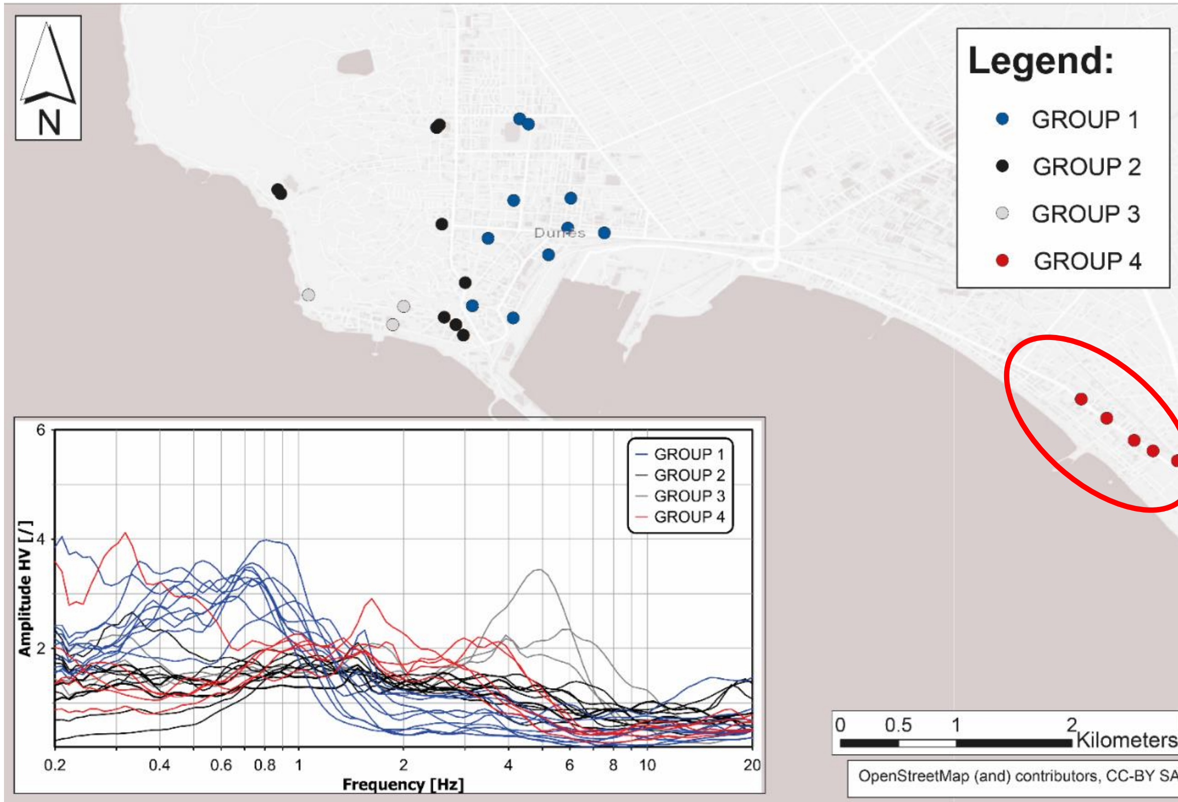

a) map of the soil categories and related predominat periods (in s) and seismic intensities (modified after Kociu, 2004); b) equal depth contour map of the bedrock showing the location of DURR seismic station (modified after Duni & and Theodoulidis, 2020)

# Geophysical measures (October 2019 survey)




Map of the geophysical measurements performed in Durrës. Noise measurements at 29 single station (HVSR) and centers of the small aperture arrays are indicated with blue and black triangles, respectively. MASW active array location is marked with a red line

# Results from seismic noise measurements



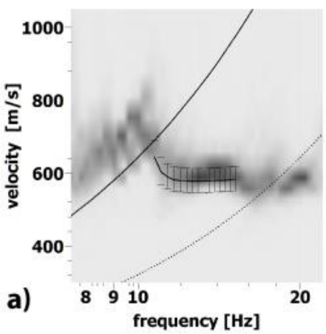


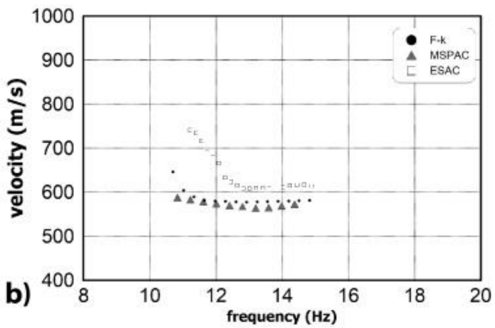
Different typologies of HVSR curves observed in the study area and their relative location on map. The most damaged area show amplitude peaks (higher than 2) at 1-2 hz frequency ($f_0$)

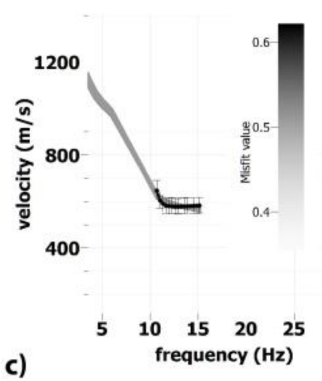
Most damaged area after the 21st September 2019 event

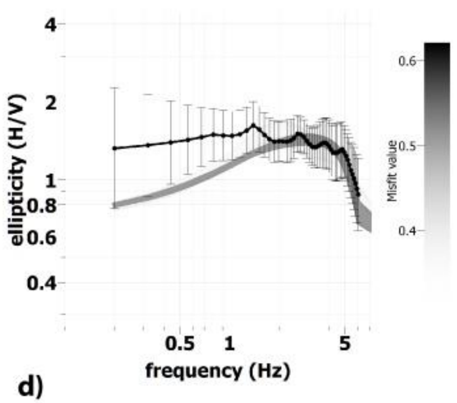
# **Results from the array surveys:** the quarry site, **Geological bedrock**

a) Rayleigh waves **dispersion curve trough F-k technique** and 2D array limits; b) Rayleigh waves dispersion curves comparison

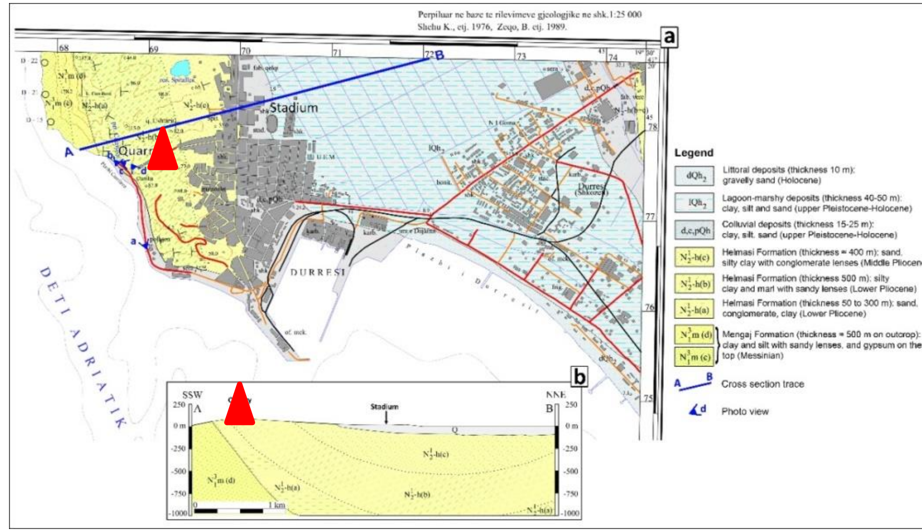


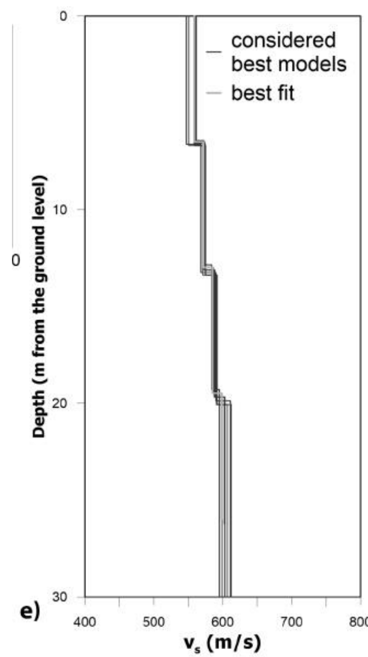




c) fitting of the dispersion curve; d) fitting of the ellipticity curves

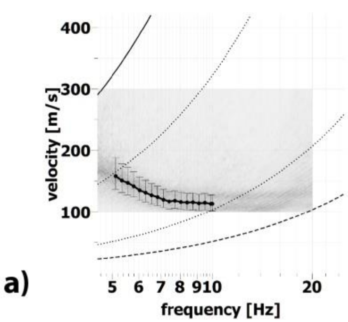


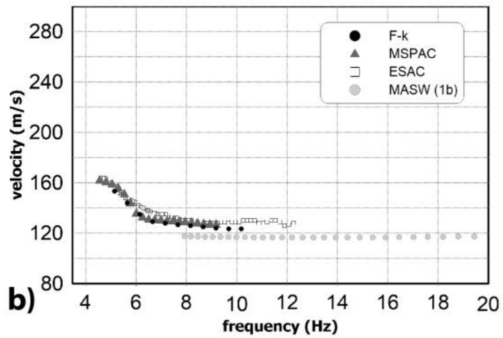



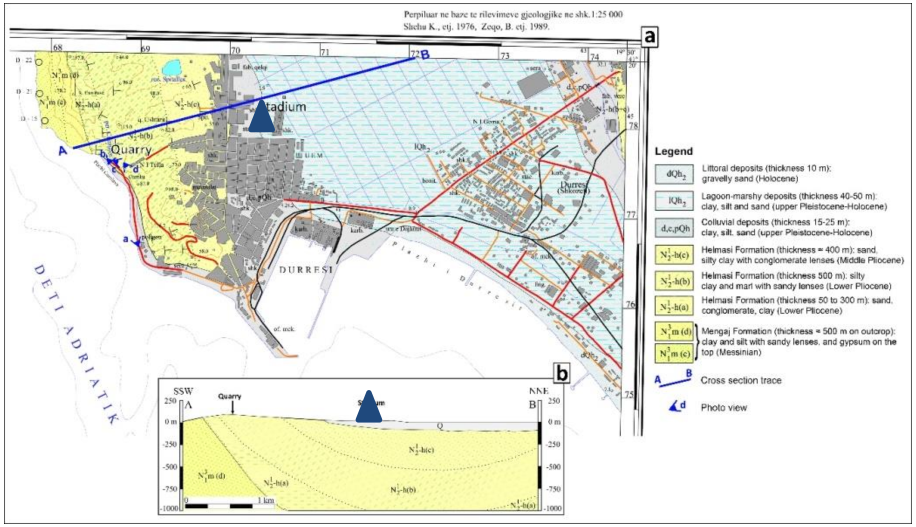

**e) considered best $V_S$ profiles** and best fit (600 m/s in the first 30 m)

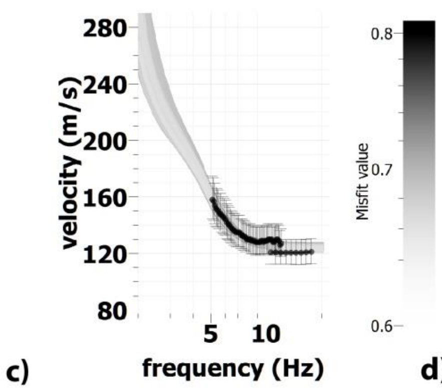
# The Stadium site: **soft cover deposits** (reclaimed marshy area); **class D soil** (Eurocode 8-EN 1998-1)

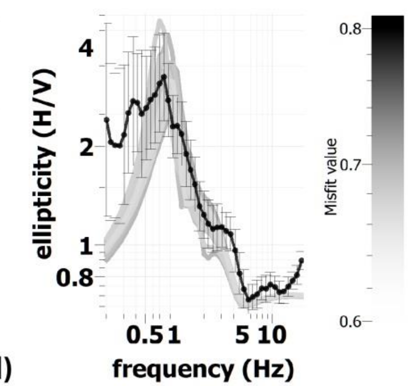
**a) Rayleigh waves dispersion curve** trough F-k technique and 2D array limits; b) Rayleigh waves dispersion curves comparison

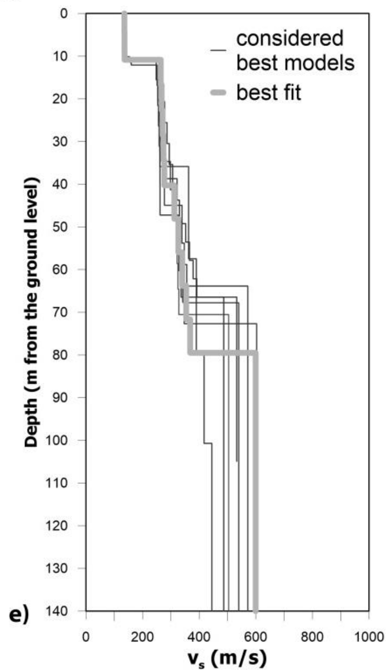



c) fitting of the dispersion curve; d) fitting of the ellipticity curve

**e) considered best $V_S$ profiles** and best fit

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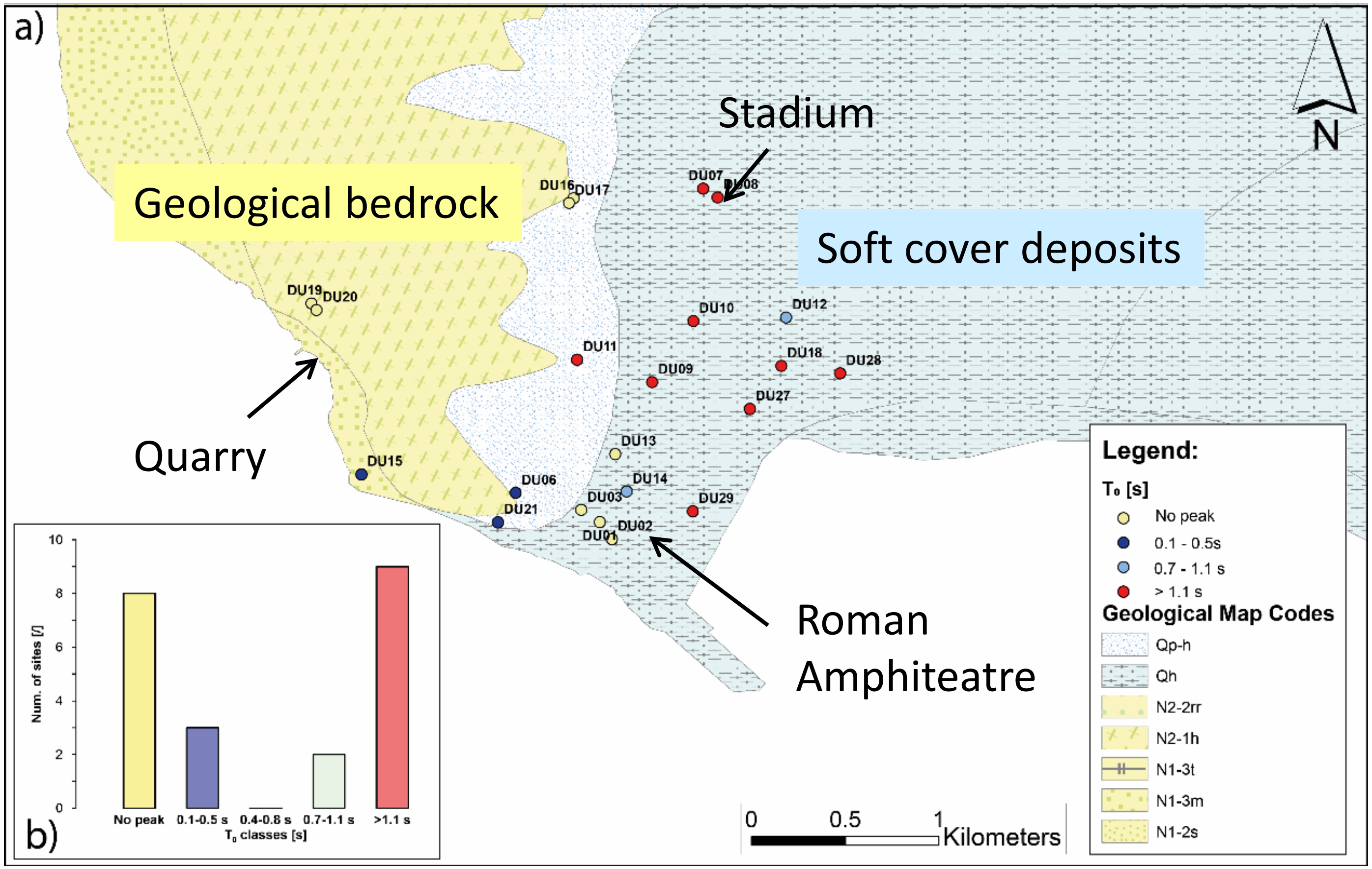
# The fundamental period $T_0$ map



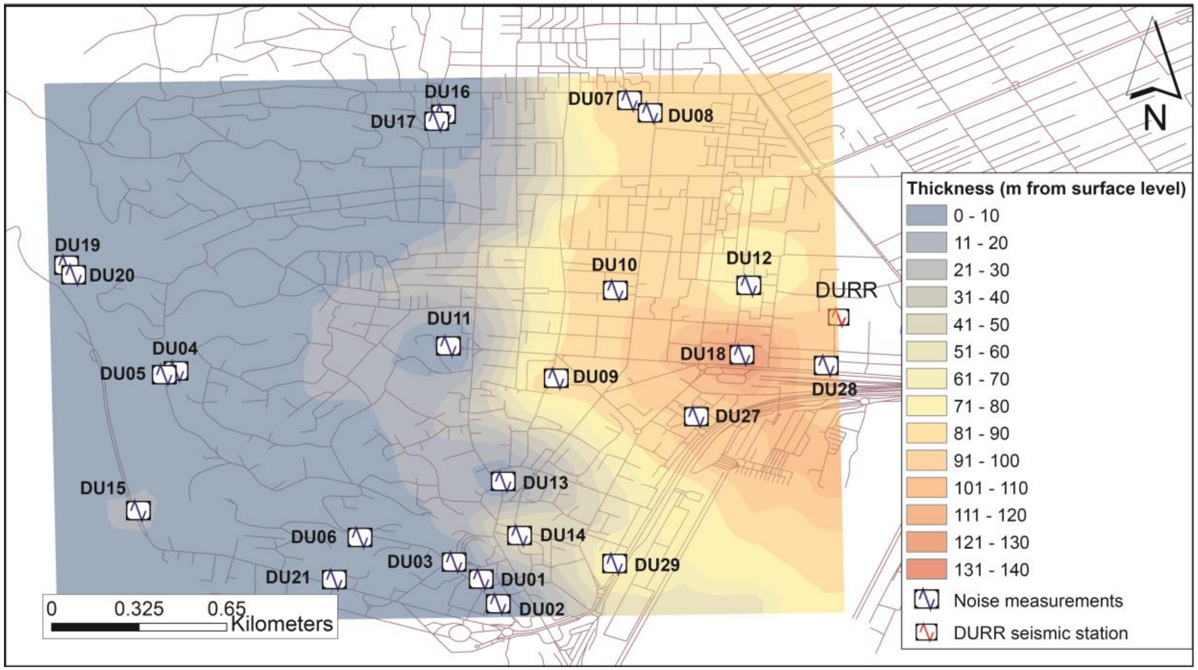

a) **fundamental period $T_0$ map** of the sediment layer assessed by HVSR noise measurements versus the number of noise measurements; b) bar chart Classes in the bar chart are grouped in: classes of 0.4-sec width according to Pergalani et al. (2019) no peak class and >1.1s T0 class.

The **frequency value $f_0$**, defined as the lowest fundamental peak of frequency with at least one amplitude of two, **was determined for each HVSR curve from noise measurements**.

Afterwards, the corresponding **fundamental periods $T_0$ as $1/f_0$ were computed**.

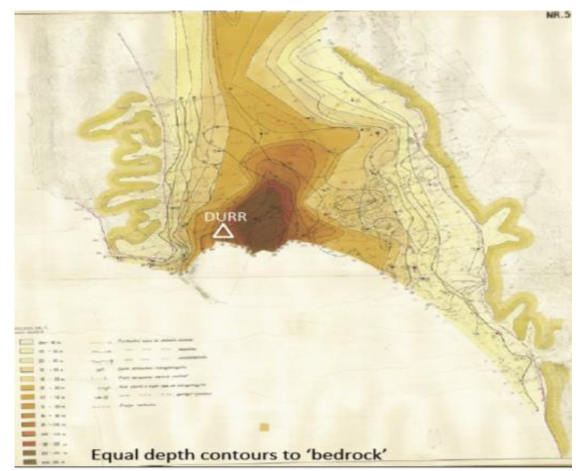
The intervals of period (0.1-0.4s; 0.7-0.8s; 0.7-1.1s) are closely linked to the **heights of buildings ($1 \le T_1 \le 4$ floors; $3 \le T_2 \le 6$ floors and $5 \le T_3 \le 8$ floors)**

# Mapping the geological bedrock




Contour map showing the **thickness h of the resonant sedimentary soft cover from $f_0$ distribution**. A geostatistics algorithm (IDW, Inverse Distance Weigth) was used to account for spatial autocorrelation and to produce the map.

The deepest values of the bedrock from the present study is comparable with results from previous maps, obtained from stratigraphic correlation and interpolation of borehole data



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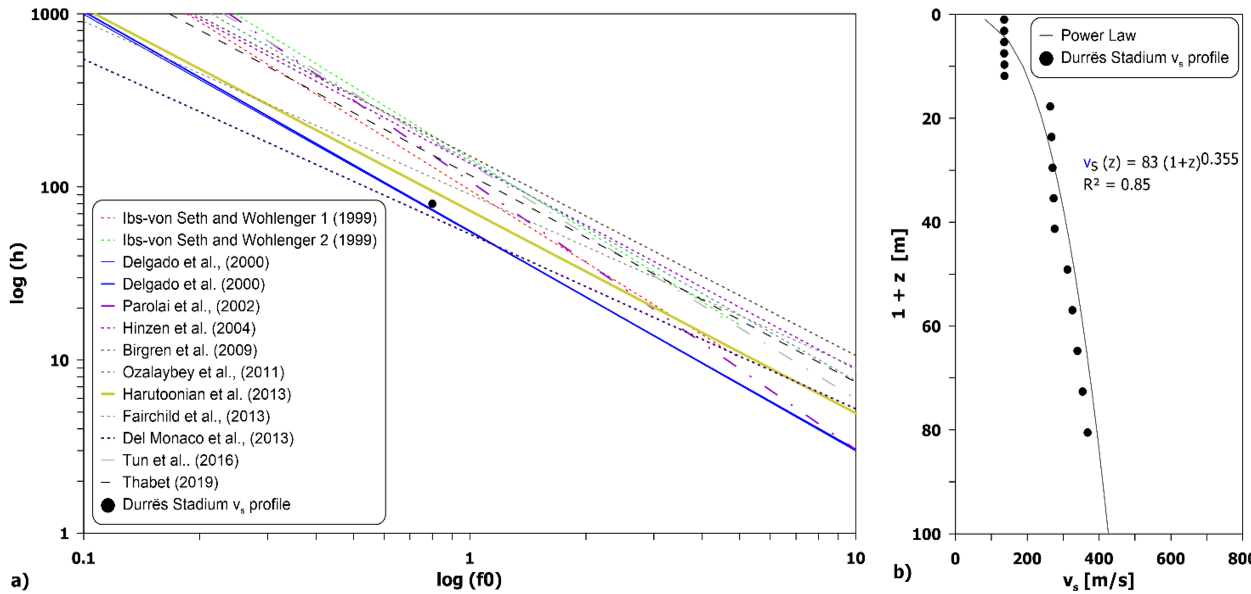
A **$f_0$ – h relation** , where h is the bedrock depth (or thickness of resonant cover), exists in the assumption of a $V_S$ profile for the sedimentary cover (D'Amico et al., 2008) and can be ex pressed in the form of the equation:

$$h \approx A * f_0{}^{\wedge B}$$

**Coefficients A and B (56; 1.55)** were chosen by plotting on the plane $f_0$ – h the only available experimental h value obtained from the Vs profile for the site that was not deployed on the seismic bedrock (e.g. the Stadium noise array), and the corresponding $f_0$ was derived from HVSR noise measurement.




a) HVSR resonance frequencies (f0) versus the depths to rock substratum (h) from the Stadium Vs profile compared with the literature relationship reviewed in Thabet (2019) and reference therein; b) Vs velocity profile at the Stadium (black points) and interpolation plot (solid black line)

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## Conclusions

1) Four classes of HVSR curves and related fundamental periods $T_0$ are recognised and mapped.

2) Two main zones are characterized in terms of Vs:

2A) a western zone with the geological bedrock, composed of overconsolidated clays and having Vs higher than 600 m/s;

2B) an easter zone with a soft cover soil (class D soil, late Quaternary marshy clays and peats), more than 80 m thick, covering the bedrock and having Vs 400 m/s.

3) A map of the geological bedrock, expressed in terms of thickness of the resonant sedimentary cover, shows deepest values of the resonant cover/bedrock boundary surface in the eastern zone. Present results confirm and strenghten those from previous studies.

4) The most damaged areas are located in the easternmost periphery of Durres, on poorly consolidated clays and peats.

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***Thank you for the attention***