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Historical earthquakes at Ischia Island and seismic hazard assessment

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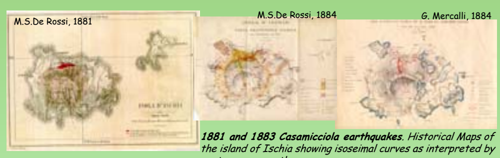
Introduction

Long-term observation of seismicity of volcanic areas showed that earthquakes are generally characterized by significantly lower maximum magnitude than tectonic areas, producing high intensities correlated to the shallow ipocentral depth and poor mechanical properties of rocks.

At Ischia volcanic island (Southern Italy) the historical seismicity shows following characteristics: high intensity values rapidly decreasing with distance, shallow ipocentral depth, local amplification of damages and strong directional attenuation of effects.

Studies of historical documentation of earthquakes occurred in the island are fundamental to localize the seismogenetic sources and to evaluate the seismic energy propagation for hazard assessment, also considering the lack of significant seismicity after the 1883 catastrophic event.

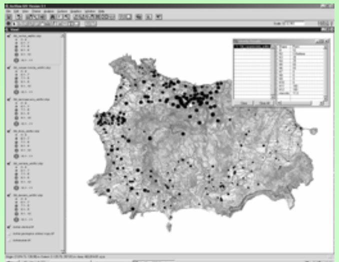


1881 and 1883 Casamicciola earthquakes. *Historical Maps of the island of Ischia showing isoseismal curves as interpreted by contemporary authors.*

The documentation of 1883 earthquake damages and their spatial distribution allow us to define focal parameters and propagation processes of seismic energy (*7,8*). This data were produced immediately after the earthquake by the *Rescue Committee for Damage Victims of the island of Ischia* and it consists of technical records that report detailed damage of buildings of the island and the ground effects. The data are accompanied by a wealth of scientific literature, iconographic documentation, technical reports and historical maps which provide a complete frame of the effects.

Comune	Examined Buildings	Examined Rooms	Buildings collapsed	Rooms collapsed	Rooms unsafe	Rooms damaged	Slight damaged rooms
Casamicciola	820	4205	667	3306	799	100	0
Lacco Ameno	390	1404	168	786	488	111	0
Forio	1562	6890	524	2921	3497	88	0
Serrara Fontana	372	1409	0	219	581	530	55
Barano	605	2029	0	236	1021	549	38
Ischia	168	854	0	9	518	280	30
Total	3917	16791	1359	7477	6904	1658	123

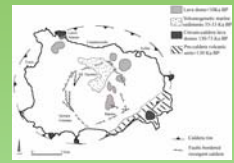
We have analyzed the damage of 3917 buildings belonging to 249 locations representative of the entire island. Each record reports: location of the building and its use; description of damage occurred in individual rooms (including cellars, farm buildings, surranding walls). In addition, information on landslides and ground effects are also reported. All these data are managed with GIS software using appropriate algorithms of spatial analysis.



Map of 1883 earthquake intensity elaborated with GIS.

Tectonic and seimicity of the island

The central sector of Ischia is made up by the Mt. Epomeo structure (787 a.s.l.), marked by a NW-SE, NE-SW and N-S system of structurally significant faults and fractures. The uplift of Mt. Epomeo is correlated to resurgence of the caldera after a large explosive eruption (55 ka B.P.) that deposited the Mt. Epomeo Green Tuff (MEGT) (*1,5,15,16,18*). A laccolith intrusion was hipothesized as source of Mt.Epomeo resurgent block producing the tectonics at its boundary and volcanic activity (*4,6,14*). The seismicity recorded in historical time is confined along the faults bordering the northern sector of Epomeo block.



Major structural and volcanological features related to resurgence process (modified by Tibaldi and Vezzoli, 1998)

Color Ortophoto of the island (CGR, 2000)

Recent dynamics of the island

Yellow point: submerged roman ruins
red point: hot springs
black narrows: maximum deflection zones (inferred by Osservatorio Vesuviano INGV levelling data, 19)

Documentation of seismicity are available starting from 1228; during 1228-1883 period numerous events exceeded VII MCS degree; the epicentral areas of earthquakes are located in the northern sector of the island. Only one earthquake were correlated with an eruption, the latter occurred in 1301-02 in the eastern sector of the island. In few cases (1228, 1863, 1881, 1883) earthquakes were followed by landslides producing serious damage; ground effects such as fracture and variation of capacity and temperature of hot spring were often observed too.

1228	Casamicciola	IX-X	700 deaths, large landslide from Mt. Epomeo
1302	Eastern area	VIII	Many buildings collapse
1557	Campagnano	VII-VIII	Collapse of the Parish Church
1762	Casamicciola	VII	Damage to houses in Casamicciola
1767	Eastern area	VII-VIII	Collapse of Rotaro's Church
1796	Casamicciola	VIII	7 deaths, serious damage in the upper part of Casamicciola
1828	Casamicciola	VIII-IX	28 deaths, 50 injured, serious damage and collapses in the upper part of Casamicciola
1841	Casamicciola	VII	Cracks in the buildings
1863	Casamicciola	VII	Collapse of dry walls, small landslides from Mt Epomeo
1867	Casamicciola	VI-VII	Buildings damaged at Casamicciola
1881	Casamicciola	IX	129 deaths, many injured, many collapsed buildings at Casamicciola and Lacco Ameno
1883	Casamicciola	XI	2333 deaths, 762 injured, many collapsed buildings at Casamicciola, Lacco Ameno and Forio

Maximum damage areas of major earthquake starting from 1796. Historical seismicity (rigth)

The catastrophic 1883 event, the last occurred in the island, represent the unique example of earthquake in volcanic Mediterranean areas which produced more than 2300 fatalities as a result of whole destruction of the town of Casamicciola and damaging of many buildings of the island (*7,8*). The catastrophic effects of this earthquake (Imax=XI degree MCS) was very local covering an area of about 3 km^2 (Casamicciola and Lacco Ameno towns) while strong attenuation effects were observed especially along the east direction.

Monte della Misericordia

Piazza della Maddalena

Damage at Casamicciola, upper part

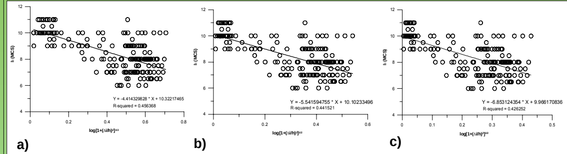
by Achille Mauri

Damage at Lacco Ameno main road (left) and Fango landslides (right)

by Johnston Lavis, 1885

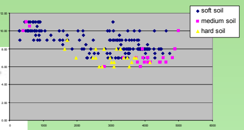
The 1883 earthquake : macroseismic attenuation

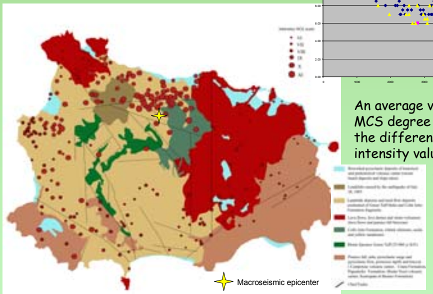
The study of historical seismicity of Ischia have shown high intensity values rapidly decreasing with distance, shallow ipocentral depth, local amplification of damages, and strong directional attenuation of effects. In order to evaluate the tendency of attenuation of intensity observed for the 1883 "Casamicciola earthquake" we use a widely intensity versus epicentral distance relations, Blake's formula (1961).



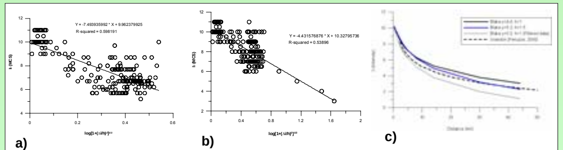
Blake's law (1961): $Io - Ii = g \log[1+(Di/h)2]1/2$:
Io = intensity at epicentre; h =ipocentral depth, Di = epicentral distance of Ii, g= attenuation coefficient. The regression line are calculated for different ipocentral depth, a) h=1km, b) h=1.5km, c) h=2km.

The observed intensity distribution and the inferred attenuation coefficients seems to be strongly influenced by the different mechanical properties of geological substrata. The data have been filtered in order to separate the different contribute of three main groups of soils (soft = reworked tuffs, medium = not reworked tuffs and hard = lavas)





An average variation of 1.3 MCS degree is calculated as the difference between the intensity values of very closely sites located on the soft substrata and lavas respectively



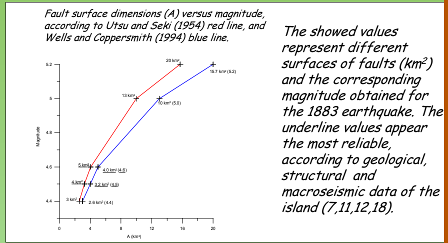
The Regression Blake's line calculated for filtered data (intensity have been reduced of 1.3 degree at distance greater than 1.5 km from the epicentre) and h=1.5, shows a very high attenuation coefficient: $\gamma = 7.5$ *(a)*

Including the felt data of the outside eastern area of the island (Procida island, Pozzuoli, Napoli, Vesuvio) until a distance of about 40 km from the epicenter we obtain $\gamma = 4.4$ *(b), similar to those calculated at Vesuvius and Campi Flegrei areas (9)*

Comparing the 1883 earthquake Grandori attenuation curve obtained by Peruzza (2000) and our Blake's curves we find best fit for h=1.5 km and $\gamma = 5.2$ *(c)*

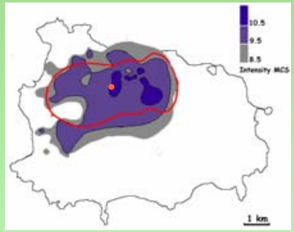
Seismic hazard

Attenuation law and source parameters are fundamental for hazard asses evaluation. The magnitude of 1883 earthquake (*7,8*) obtained taking into account the reliability of formulas utilised in literature, shows values be 4.3 and 5.2. Considering these values we can infer the possible fault surfa the earthquake.



The showed values represent different surfaces of faults (km^2) and the corresponding magnitude obtained for the 1883 earthquake. The underline values appear the most reliable, according to geological, structural and macroseismic data of the island (7,11,12,18).

Interpretation of source parameters has been inferred comparing the Aki Richards point-source model (1980) with the macroseismic map obtained toward Krighing interpolation of data.



Comparison between macroseismic map and synthetic isoseismal obtained by double co point source approxim (Aki and Richards, 19 with following parame

Strike $(\phi) = 260°N$
Dip $(\delta) = 90°$
Slip $(\lambda) = 250°$
Depth $(h) = 2$ *km*
Epicenter

The high housing density and high economic value exposed make the islan considerable interest for mitigation of the seismic risk. The study of hist seismicity allow us to define:

- the seismogenetic sources are located along the faults bordering Mt.Ep the northern sector of the island, where probably brittle processes domi respect to the southern one where high geothermal gradient have been r (max 180°C km^{-1});

- high intensites are expected, even if earthquake magnitude is moderate because of very shallow source and soft soils outcropping. The complexity structure and the fuzzy sequence of the macroseismic data make it diffi evaluate the return period of the earthquakes

-strong attenuation processes are observed in the island, particularly alon eastern and southern sector where high fracturation of rocks, high temp and low rigidity of the medium prevail over source effects;

-magmatic pressure and regional stress, joined to load of Epomeo block thermal stress act in the island producing seismicity.

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