# Near Surface Geophysics Contribution For First Level Seismic Microzonation Studies For The Municipality Of san Vito Lo Capo, Western Sicily, Italy

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## Introduction

Recent studies, carried out by the University of Palermo, allowed to define different seismic aspects of the area of San Vito Lo Capo, located in the north-western Sicily, Italy.

These investigations were helpful to recognize and highlight, on a sufficiently detailed scale, the lithostratigraphic and morphological characteristics of the study area. Moreover, this approach has a particular importance in understanding which features could induce seismic shaking amplification episodes, instability phenomena and earthquake-triggered permanent deformation.

These analyses underlie the Seismic microzonation (SM) of an area, which represents a useful tool for seismic prevention and risk assessment. The first level SM studies, applied to the Municipality of San Vito Lo Capo, has been based on the collection and analysis of pre-existing data and integrated by new *in situ* investigations. Finally, the interpretation and correlation of these data allowed to identify seismic bedrock depth and the homogeneous microzones from a seismic perspective (MOPS).

## Geological and geomorphological setting

The area belonging to the Municipality of San Vito Lo Capo is located on the north-western coast of Sicily and extends from the promontory of Capo San Vito, to the north, to the village of Castelluzzo and the Zingaro natural reserve to the west and east respectively. The geological lithotypes that characterize the area are limestone and recent clastic-terrigenous terrains. Morphologically the area is characterized by a main contrast between mountains (Monte Monaco - Pizzo di Sella ridge) and flat and tabular areas hosting San Vito town and Macari and Castelluzzo villages. The mountain reliefs are characterized by several slope breaks, steep slopes and

detachment niches, while the flat sectors present extensive terraced surfaces and debris deposits.

The perimeter of the area subjected to first-level SM corresponds to the main urban center of San Vito Lo Capo and the areas of Macari and Castelluzzo fractions.

**Definition of the basic hazard for seismic classification**

Through the reconstruction of the seismic history of an area it is possible to evaluate the danger of the site and consider the possible impacts of an earthquake on the territory in time. The seismic events that characterized the area were chosen by consulting the Italian Macroseismic Database (DBMI15, Locati et al., 2022), the Italian Earthquake Parametric Catalogue (CPTI15 v3.0) (Rovida et al., 2021), the Italian Macroseismic Historical Archive (ASMI; Rovida et al., 2017) and the Catalogue of Strong Earthquakes in Italy (461 BC-1997) and in the Mediterranean area (760 BC-1500) (CFTI5Med; Guidoboni et al., 2018).

The main historical earthquakes that from the 4th century BC had significant macroseismic effects in Western Sicily and those that, starting from the 1900 have recorded significant effects in the municipality of San Vito Lo Capo include the Mw 6.41earthquake in the Belice Valley, dated 1968, and the Mw 4.79 earthquake of 29.05.1988 with epicenter near the Egadi islands.

To reduce the effects of the seismic shaking expected on the national territory, with a view to safeguarding human life, Italian legislation has made a reclassification of the seismic hazard of the entire country. This classification is based both on the intensity and frequency of past earthquakes and on the application of technical standards for constructions in seismic classified areas.

According to the latest seismic classification of the Region, dated 24.02.2022, the municipality of San Vito Lo Capo falls in an area characterized by a medium basic seismic hazard since it has maximum acceleration values to the ground (ag) between 0.15 g and 0.25 g.

For the evaluation of the basic seismic hazard of an area an important element is the seismogenic zonation of the Italian territory. The recent seismogenic zonation ZS9 (Meletti and Valensise, 2004) divides the entire Italian territory into 36 zones. According to this the study areas do not fall into any seismogenic zone.

As regards the definition of the seismic hazard of the area, reference was made to the data published on the web database of the National Institute of Geophysics and Volcanology (INGV) (http://esse1.mi.ingv.it) described by Meletti et al. (2006). In this dataset was researched the values of maximum horizontal acceleration to the ground, named ag, with probability of excess of 10% in 50 years. The examined area presents ag values between $0.050 < ag < 0.075$ g.

Finally, a fundamental element for the classification of the seismicity of an area is the recognition of active and capable faults. For this purpose we consulted the ISPRA online database which is

based on the development of the project ITHACA (2019). In particular this project was realized to research and describe the capable faults, defined as faults that potentially can create permanent coseismic deformation on the surface. According to this catalogue the area does not present active and capable faults. Moreover, by analyzing the DISS (Database of Individual Seismogenic Sources) catalog, published by INGV (2021), the territory of the Municipality of San Vito Lo Capo does not result affected by any seismogenic element and the presence of active and capable faults is not reported.

Nevertheless, a fault located in the western part of San Vito Lo Capo and indicated in pre-existing geological cartography, results poorly investigated and for this reason it was not possible to clearly identify deformation or morphostructural evidence of recent movements. Therefore, on the basis of the available data it was not possible to reconstruct the extent of the fault displacement and the age of the movement.

**Data collection**

As required by the SM guidelines for the study of first level, a collection of pre-existing geognostic and geophysical data has been used. These was appropriately selected basing on the reliability of the results that is linked to the methodology data acquisition and processing.

As regards geognostic surveys, ten pre-existing continuous core drilling were used to improve the information about the subsoil and to calibrate the depth of the seismic bedrock since five of them reach the geological substrate.

Geophysical data analyzed included Seismic Refraction surveys (SR), Vertical Electrical Soundings (VES), Electrical Resistivity Tomography (ERT) and noise seismic data elaborated using the Horizontal to Vertical Spectral Ratio (HVSR) method.

52 SR investigations were carried out during public or private professional studies for the determination of the compression waves velocity useful to define the bedrock depth. These surveys were realized both in San Vito Lo Capo, Macari and Castelluzzo. The depth of investigation of almost all surveys did not exceed ten meters due to the detection of the seismic bedrock within this depth in all investigated areas.

In a large area upstream of the village of Castelluzzo seven VES were performed, whose interpretation allowed to reconstruct the local stratigraphy up to depths of about 100 m below ground level. The results of these surveys cannot be fully validated because due to the lack of fundamental information concerning the acquisition parameters and the resistivity curves obtained from the measured values.

In addition, other information was provided by five ERT carried out in the town of San Vito Lo Capo.

The 47 HVSR surveys considered include 32 measures carried out in the 2012 and 15 measures carried out in February 2022. These latter were realized for the geological study preparatory to the editing of the General Town Plan of the Municipality of San Vito Lo Capo. In particular 21 surveys were located within San Vito Lo Capo, 12 in Macari and 14 in Castelluzzo. The HVSR surveys were located in an almost homogeneous distribution on the most urbanized territory. All HVSR measurements, acquired with 3D seismic velocimetric sensors, were reworked and reinterpreted in the light of the available data.

**Data analysis and definition of the subsoil model**

The HVSR surveys were interpreted trying to identify the mean frequency peak within the frequency window of 0,1-20 Hz, as well as secondary peaks that may be present. In almost all HVSR measurements low frequency peaks were recognized, generally between 1 Hz and 3 Hz and other peaks at higher frequencies, around 20 Hz.

The recognized peak frequencies were used to realize the frequency maps for each area, in which the spatial distribution of the HVSR surveys is reported together with peak values recognized.
HVSR curves that presented stratigraphic peaks were interpreted with seismic velocity models, constraining the inversion and interpretation with the available geological and geophysical data to compute the depth of the seismic bedrock.

Based on the results of the seismic tomography, which show seismic velocities greater than 800 m/s already in layers a few meters deep, the low-frequency peaks (1-3 Hz) of the HVSR curves have been considered as caused by very deep stratigraphic interfaces. Conversely the cover/bedrock interface could be responsible for the higher frequency peaks (around 20 Hz). The bedrock depth model, represented in Fig. 1, shows that investigated areas are characterized by limestone rocks that constitute the shallow seismic bedrock. Above these rocks a coverage of a few meters is present. In particular, the area of the town of San Vito Lo Capo shows very shallow seismic bedrock, excluding a restricted area characterized by the presence of an ancient quarry filled by heterogeneous material. Even the area of Castelluzzo shows few meters of coverage above the seismic bedrock. Finally, the Macari area shows greater depth variations of the seismic bedrock, reaching maximum value of 12 m b.g.l..

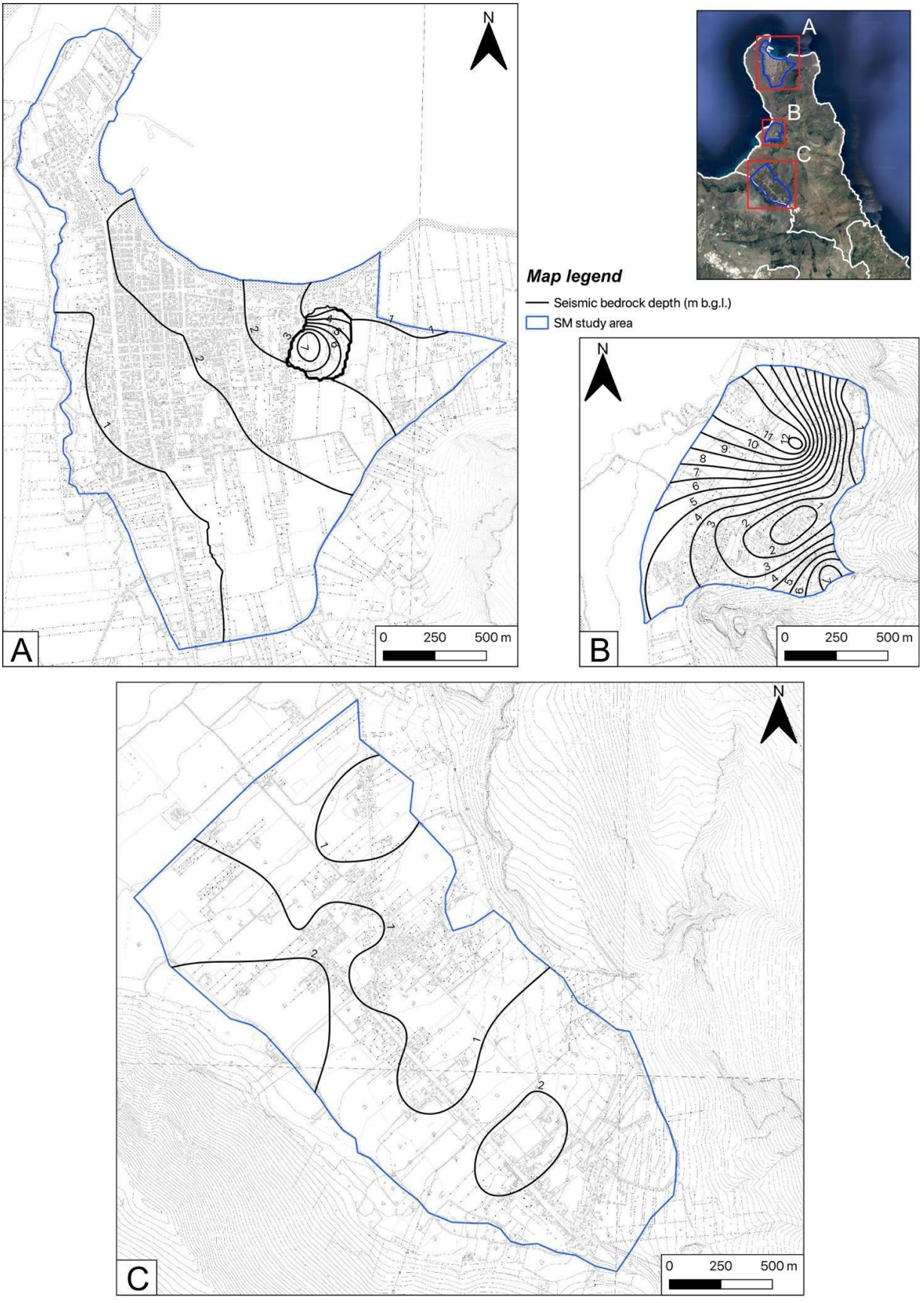
N
A
0 250 500 m
B
C
Map legend
Seismic bedrock depth (m b.g.l.)
SM study area

Fig. 1: Maps of the bedrock depth (Vs>800 m/s) for San Vito Lo Capo (A), Macari (B), Castelluzzo (C) areas.

**Map of homogeneous microzones in seismic perspective based on first level studies**

The processing of the map of homogeneous microzones in seismic perspective (MOPS) is based on the criteria defined by "Gruppo di lavoro MS" (2008). Basing on the available geological, geomorphological and geophysical observations three different categories were identified:

A first category is that of *stable zones*, where no local effects of amplification of the seismic shaking are hypothesized. These zones present an outcropping geological and seismic substrate (Vs > 800 m/s), characterized by flat morphology or inclined less than 15°; stable areas can present a thickness of cover deposits less than 3 m. According to these features two stable zone, 1012 and 1022, were defined.

A second category is constituted by *stable zones susceptible of local seismic amplification.* In these areas the amplification of the seismic input is connected to the presence of a rigid ground (Vs < 800 m/s) outcropping or covered by non-cohesive soils with thickness less than 3 m. Belong furthermore to this category outcrops anthropogenic, eluvial, colluvial and debris deposits characterized by thickness greater than 3 m and Vs less than 800 m/s.

In particular, the 2099 zone presents heavily weathered and fractured limestone on the top and silico-clastic deposits up to a maximum of about 12 m. A debris cover characterizes the 2001 zone, while the 2002 and 2003 zones are characterized by alluvial soils and beach deposits respectively. A cover of anthropogenic origin, characterized by the presence of heterogeneous and heterometric material, defines the 2004 zone.

Finally, two *zones of attention for instability* were defined, on the basis of the type of movement and the state of activity (landslides): the 30112001 zone that presents active rockfall and rock topple and the 30152099 zone characterized by widespread erosion processes. All the described MOPS for the three examined areas are shown in Fig. 2. As regards the poorly investigated fault located in the western sector of the San Vito town, reported in the pre-existing cartography, a buffer zone was mapped.

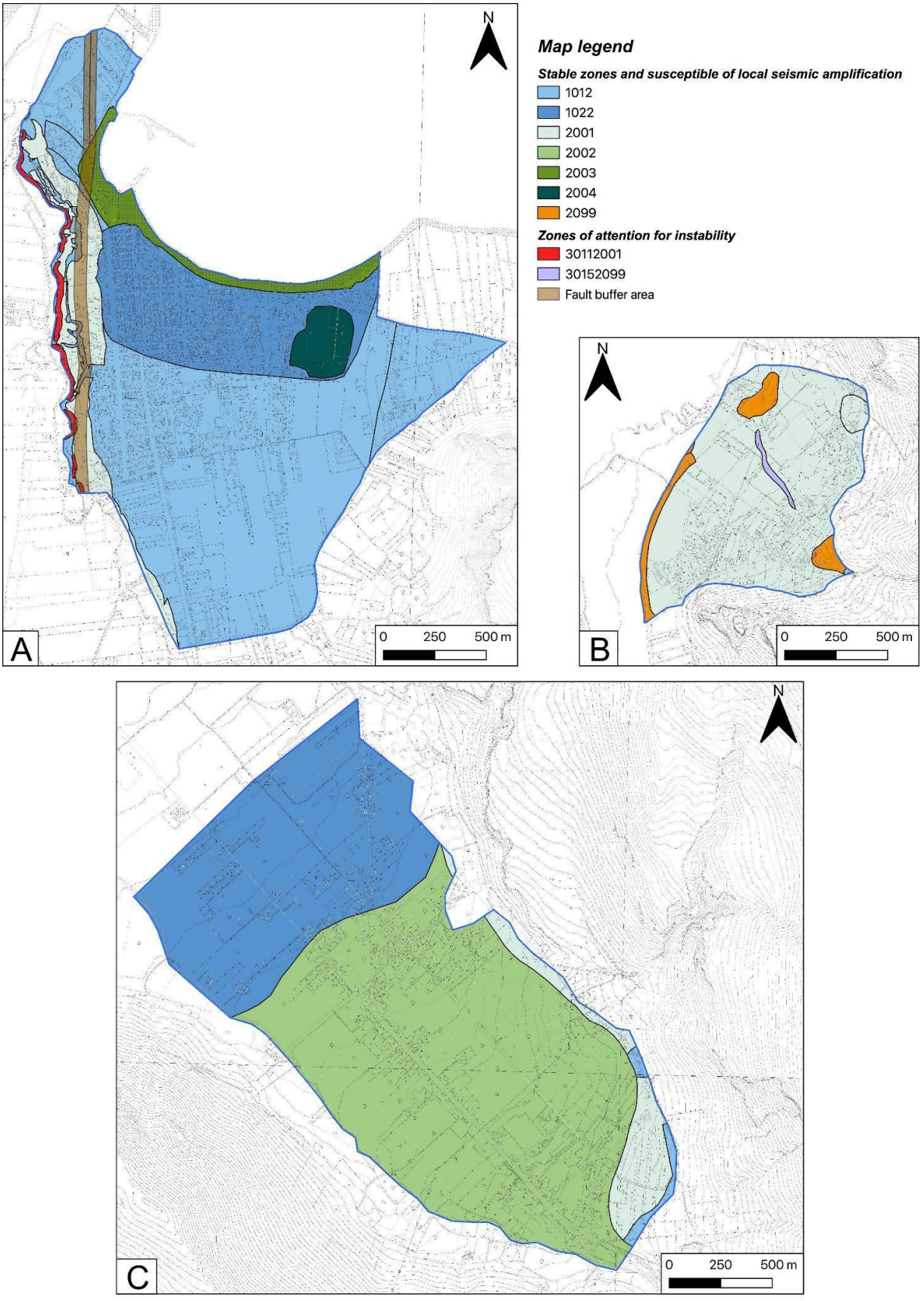
N
Map legend
Stable zones and susceptible of local seismic amplification
1012
1022
2001
2002
2003
2004
2099
Zones of attention for instability
30112001
30152099
Fault buffer area
A
0 250 500 m
N
B
0 250 500 m
N
C
0 250 500 m

*Fig. 2: Maps of the mops for San Vito Lo Capo (A), Macari (B), Castelluzzo (C) areas.*

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