Report of the Short Term Visit in CNR –ITABC , Rome Italy

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Period of Visit April 16, 2015 to April 29, 2015

As it is not possible to know what will happen in the future, in order to estimate likely earthquake hazards, it is necessary to find out what happened in the past and extrapolate from there. The purpose of this visit was to examine whether geophysical techniques can be used to address some fundamental questions related with the safety and protection of archeological sites. Discussed questions related to when and where have large earthquakes happened in the past in the Mediterranean region? How archeological evidence contribute to our scientific understanding of earthquake activity?

During the visit it was analyzed the kind of data, which is of use to the earth scientist to assess earthquake hazard. One of the crucial to assess past events is the distribution of the intensity of an earthquake that is the degree of the severity of damage or shaking, at as many sites as possible, including those at great distances from the epicenter where the shock was felt. Knowledge of the effects of the event on the ground itself is also needed and of its association with primary effects, such as faulting and secondary effects, such as landslides and seismic sea waves. In addition information, which are of interest to the earth scientist and engineer, which need to be assessed from written sources or from archaeological evidence, are the location (epicentral region) and size (magnitude) of an earthquake; that is: (a) where and how large was the area of maximum destruction, and (b) how far the shock was felt. Other information such as the human and material losses incurred, the social and economic impact and the consequences of the event are of interest more to the historian than to the earth scientist, although this kind of information can help to assess the size and magnitude of the event.

Historical sources report that Mediterranean Archeological sites have experienced considerable earthquake ground motion in the past, even though it is quite far from high-magnitude seismogenic sources. Damage distribution seems to be predominantly controlled by ground shaking amplification related to local soil conditions. In this context a multidisciplinary research approach must be conducted to determine the seismic microzonation in the areas of Archaeological Interest

One of the approached discussed based on the seismic site response of historical centers based on a robust subsoil model which integrates a large amount of available and original geological, geophysical and geotechnical data. Investigation of the physical phenomena responsible for site effects shows that ground motion distribution is mainly controlled by 1D resonance phenomena and 2D effects associated with soft alluvial valleys, topography and the morphology of anthropogenic deposits.

The Nakamura (1989) method is based on the spectral ratio of horizontal to vertical (HVSR) components of microtremors recorded on surface ground using one single seismological station considering that the vertical component is not amplified by the near surface layers. The method was implemented with the purpose to identify the fundamental frequency and the associated amplification of a geological structure subjected to seismic motion. The derived HVSR peak frequency is related to the fundamental frequency and the HVSR amplitude is related to the amplification of the investigated site (Nakamura 1996, 2000), while the relationship between fundamental resonance frequency, thickness and S-wave velocity of sedimentary deposits (F_0=Vs/4h) is also given by Nakamura (1996, 2000). Nakamura (1996) concluded that the H/V ratio: 1) presents stability at the fundamental frequency F_0 and 2) is a valid estimator of ground fundamental frequency due to multi-reflection of SH-wave in the surface layers, regardless the degree the Rayleigh wave effects. The main three observations, considerations and assumptions of the Nakamura (1989, 1996, 2000) methodology (in association with the purpose of this paper) are: 1) the effect of the Rayleigh waves on H/V peak frequency of ground seismic motion, 2) the vertical component is not amplified at the fundamental frequency F_0 and 3) the horizontal to vertical spectra ratio of a rock site (for a wide frequency range 0.2-20 Hz) is close to unity (Nakamura, 1989). More theoretical background and assumptions of the method are given in Nakamura (1989, 1996) and in the revised explanation (Nakamura, 2000). For the purpose of this study the HVSR methodology using microtremor is used to identify the resonance frequencies of a Basin and the HVSR amplitude is considered as a lower representation of the ground amplification.

Microtremor recordings are collected using a single seismological station. The H/V spectra ratio for each time window is derived by the division of the smoothed geometric mean of the two horizontal components over the vertical component. The H/V ratios of the selected windows are averaged and the average HVSR spectra ratio, the H_{NS}/V and the H_{EW}/V ratios of the selected time series window and their standard deviation estimates of spectral ratios calculated.

During the visit results of HVSR method for historical sites in Crete were presented.

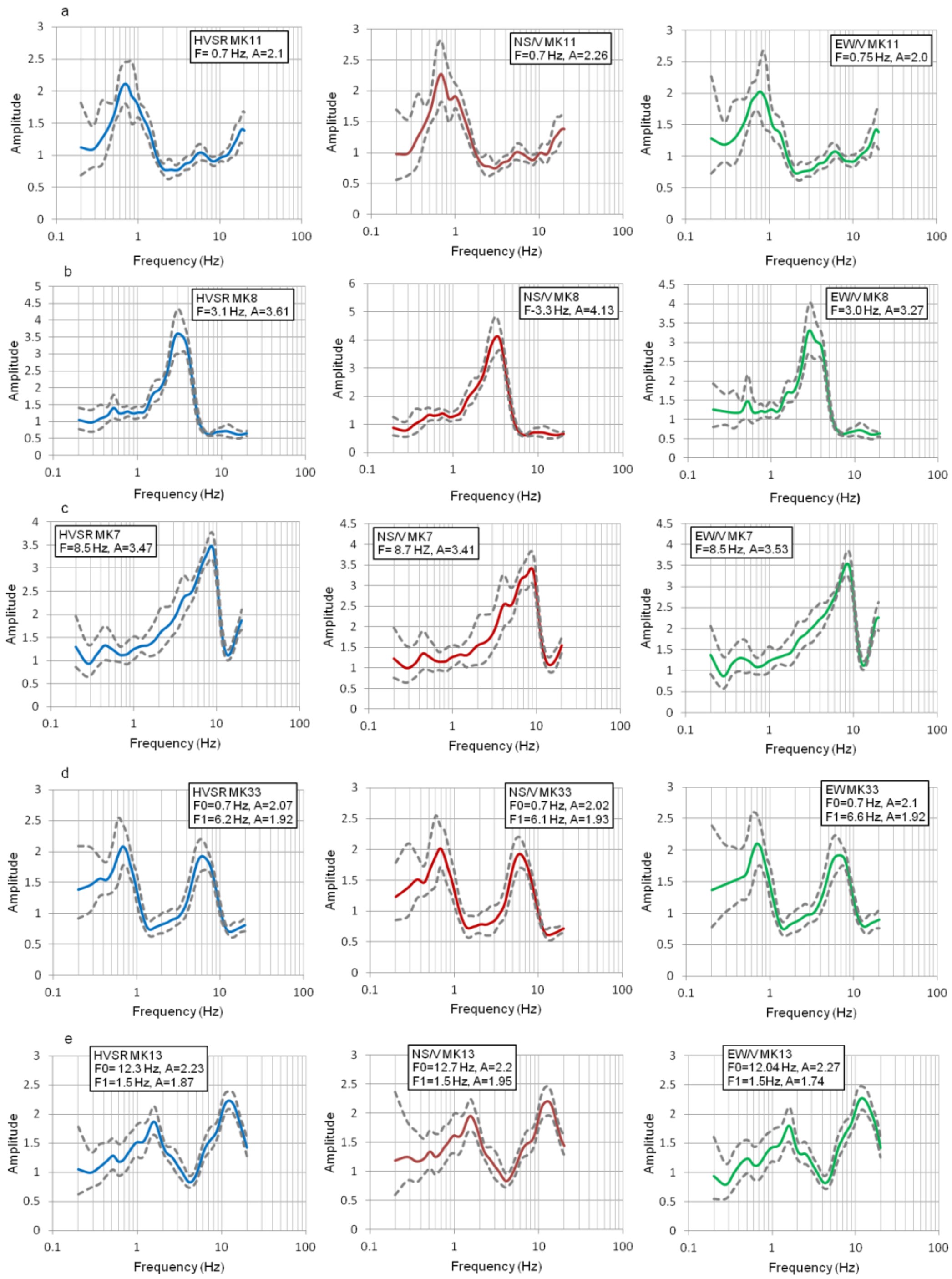


Fig.1 Examples of the typologies of HVSR, H_{ns}/V, H_{ew}/V using microtremors for site effects evaluation in the centre of Kastelli-Kissamos Basin. a) one HVSR peak at low frequencies, b-c) one HVSR peak at medium

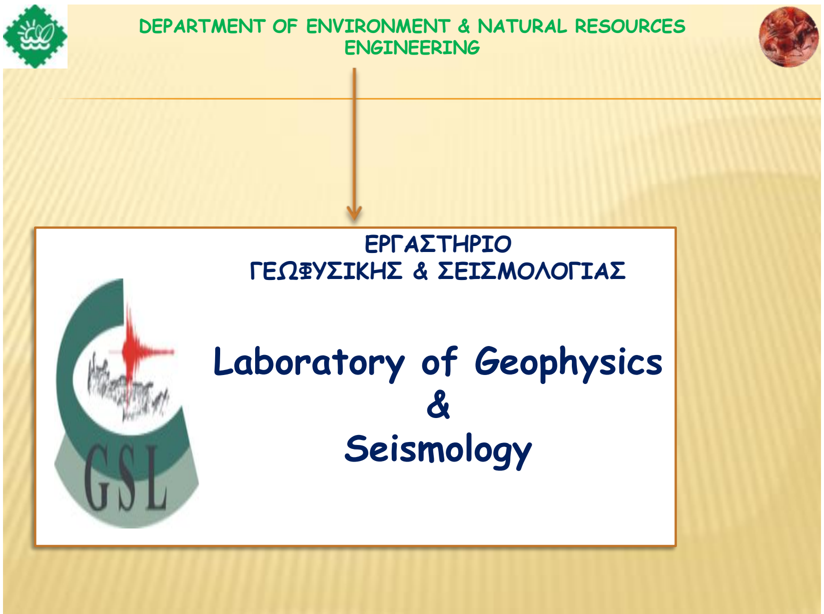
frequencies, d-e) two amplified peaks. The horizontal scale of the HVSR curves represents the frequency range (0.2-20 Hz). The vertical scale represents the HVSR amplitude. The grey dashed lines correspond to the standard deviation of each H/V, H_{ns}/V, H_{ew}/V curve. The blue line of the curves represents the average H/V ratios of microtremor recordings. The red and green curves represent the Hns/V and Hew/V ratios, respectively

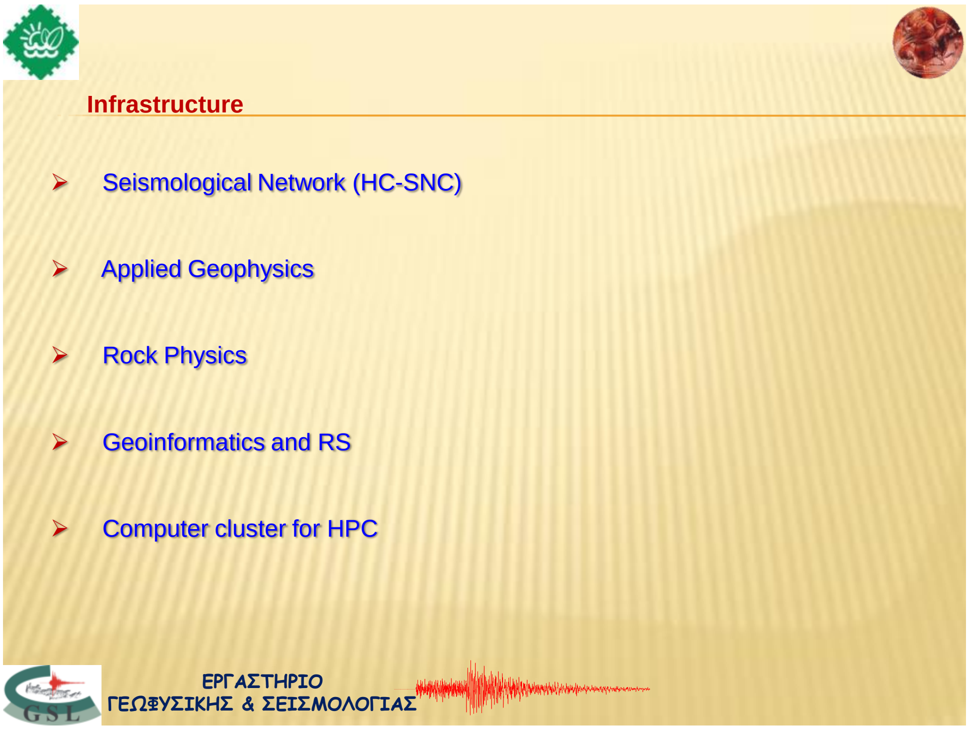
One of the methods that could be used to extract structural information in Archeological sites is ERT (Geoelectrics). Geoelectrics is one of the most reliable prospecting tools in the field of Cultural Heritage, thanks to the technological and methodological developments in recent years, which have made it a fast target-oriented method. The electrical resistivity parameter, on which the method is based, has such a large variability so as to allow the great majority of the structures and bodies of archaeological and architectural interest to be readily distinguished, in principle, from the hosting material. To enhance the resolution power of the method, a great help is provided by the recently developed in CNR-ITABC electrical resistivity tomography (ERT) approach, which involves the acquisition and processing of large datasets. We discussed the results of an ERT survey, carried out in different Archeological sites and the possibility of further Engineering application. The method is based on the measurement of the electrical potential arising from an electrical current flowing into the ground from a point source of current (a grounded electrode). In practice, there is always a device of four electrodes used to measure the ground resistivity: two are used for injecting a current of intensity I and two for detecting a voltage (potential difference) $\Delta\varphi$.

For all of the devices the theoretical solution is basically a superposition of the fundamental equations for the potential from a current point source with appropriate sign for the current. The formulae for evaluating the resistivity of the ground are a product of the impedance $\Delta\varphi/I$ and a geometric factor with the units of length which depends on the geometry of the four electrodes. However, as the resistivity is an intrinsic property of a homogeneous material and the subsoil is generally a complex distribution of different materials with different resistivities, the key concept of apparent resistivity, ρ_a, is defined. In simple terms, ρ_a is a volumetric average of a heterogeneous half-space, except that the averaging is not done arithmetically but by a complex weighting function dependent on the 4-electrode device and how it is used. In near-surface investigations, as in the archaeological prospection, the dipole-dipole is the most convenient 4-electrode device, since it provides a very detailed lateral bounding of vertical features. The DD device is normally used in profiling mode to map lateral as well as depth variations of the resistivity.

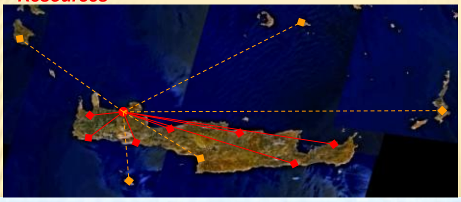
Surveying and mapping an archaeological site is an art, verifying the cause of damage is science. Without to apply modern technologies it is difficult to understand the Archeoenvironment and the vulnerability of the Archeological site in a Natural disasters. Engineering knowledge and the ability to bring historical information to bear on archaeological remains add an important dimension to the analysis towards safety of Cultural Heritage.

Selected parts of presentations given during the stay in CNR-ITABC

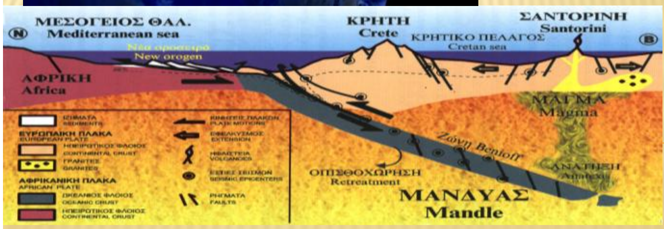




➢***Seismological Monitoring of the South Aegean seismicity using innovative Satellite monitoring network. Seismic*** ***Security of Energy Resources***



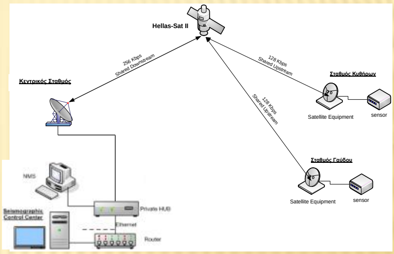
Crete: A subduction zone



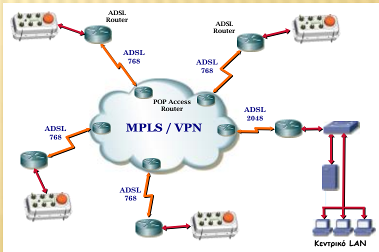
(HC-SNC)

GURALP CMG40T

- 24bits- REFTEK DAS-130
- GPS Garmin
- MPLS IP-VPN over ADSL)
- Sattelite (single-hop 256KHz@F2 Hellas Sat II iDirect iNFINITI ι Private Hub at the Central Station)



Τοπολογία κεντρικού σταθμού



ΕΡΓΑΣΤΗΡΙΟ
ΓΕΩΦΥΣΙΚΗΣ & ΣΕΙΣΜΟΛΟΓΙΑΣ

(HC-SNC)

Gavdos, HC-GVDS

Ferma-Ierapetra HC-FRMA

Infrastructure

- Electrical tomography IRIS Syscal electrodes sp. 230m
- Sesimic tomography Geometrics 24 channels max sp. 215m.
- TEM-Fast for soundings with a max loop of 100m.
- VLF - T-LVF .
- Magnetometer Geometrics- MT syetem .
- microtremeors Lennartz 3-D with datalogger City Shark II.

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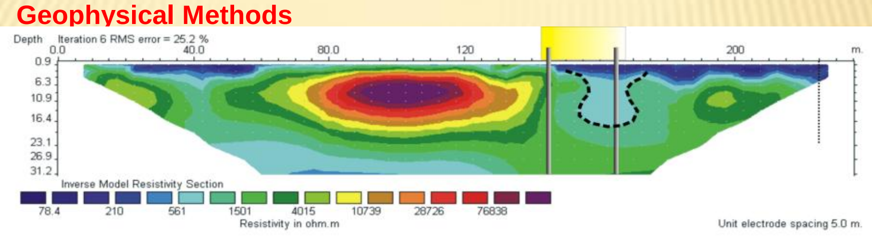
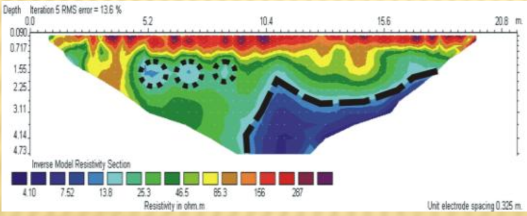
Laboratory of Geophysics & Seismology
Technological Educational Institute of Crete

Innovative Geophysical Techniques to support Decision making in Engineering. **Investigation of Waste Disposal Areas Using Geophysical Methods**

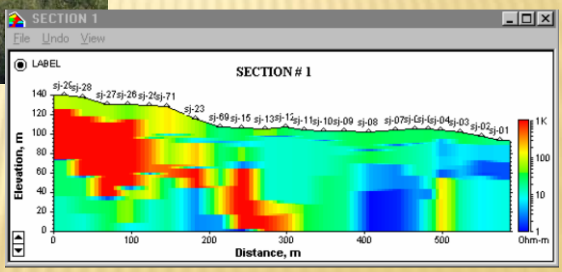




Geophysical Investigation of Soil Properties . Example from Knossos Palace

Applied Geophysics

TEM-Fast



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ΓΕΩΦΥΣΙΚΗΣ & ΣΕΙΣΜΟΛΟΓΙΑΣ

Applied Geophysics

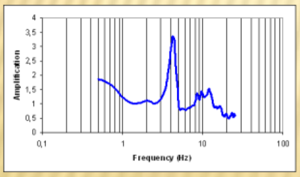
Seismic Tomography (Geometrics)

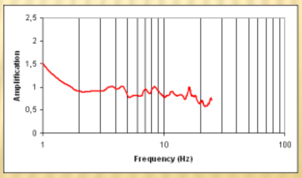
Microtremors for Cultural Harritege in Chania

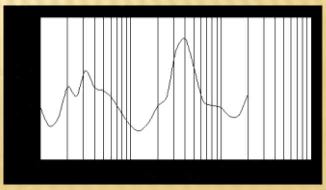
Historical Building – Manicipality of Chania

Venizelos Building

Venecian Light in the Old port of Chania







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Rock Physics

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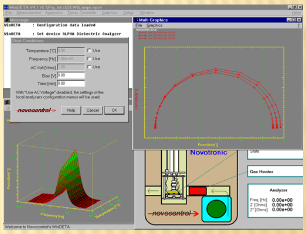

Dielectric Spectroscopy (BDS) up to 1600K and strees till to fracture.

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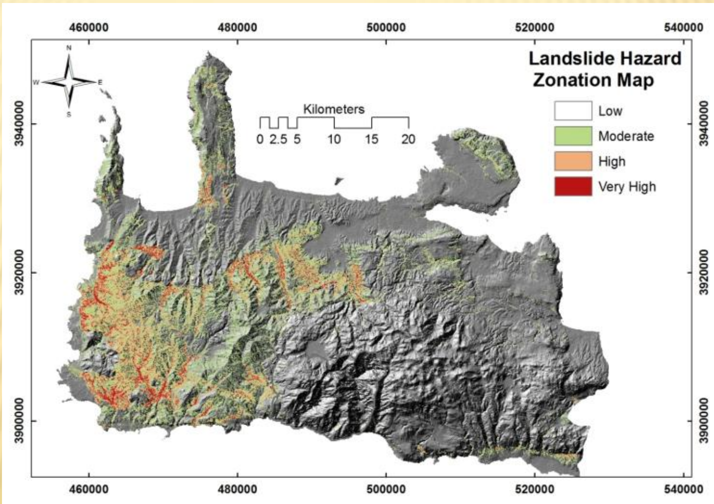
Geoinformatics and RS



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