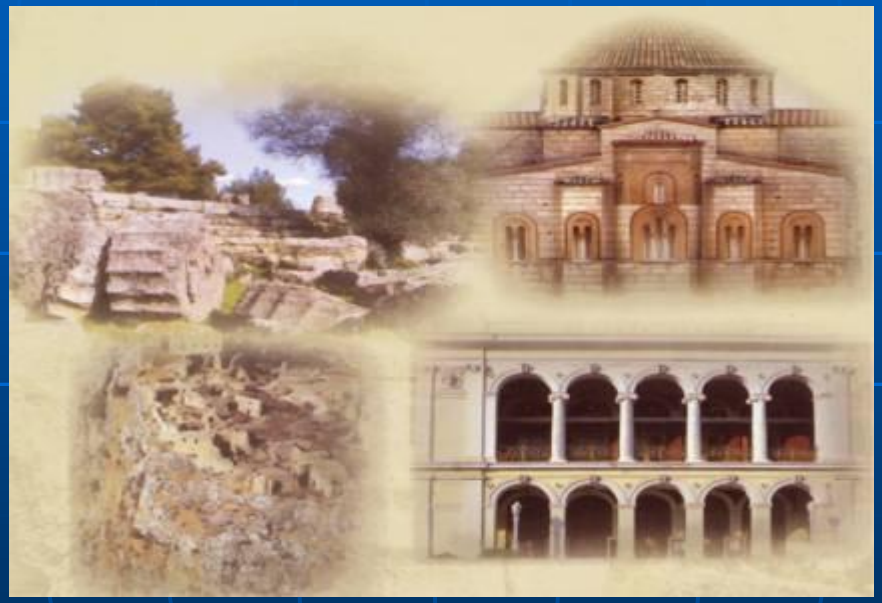
PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

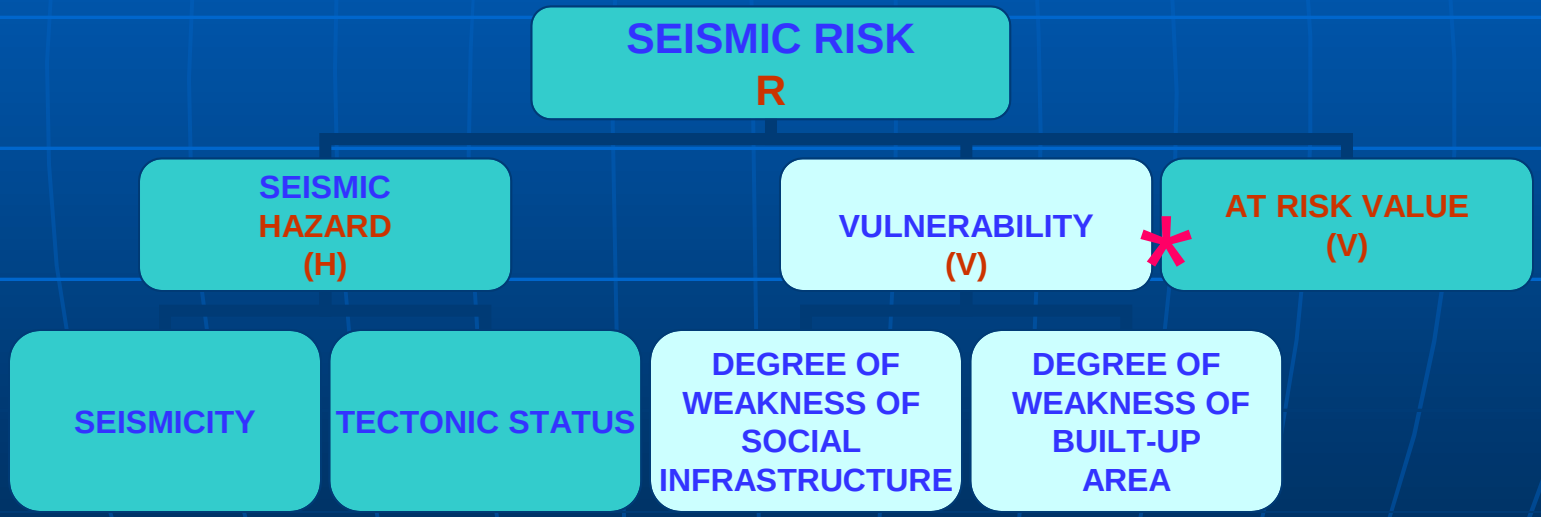


R.PAPADHMHTRIOU, L.PELLI

EUROPEAN CENTER OF PREVENTING & FORECASTING OF EARTHQUAKES

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

Confronting the problem



R=H*V*V

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

R=H*V*V

Reduction of the Vulnerability !!!

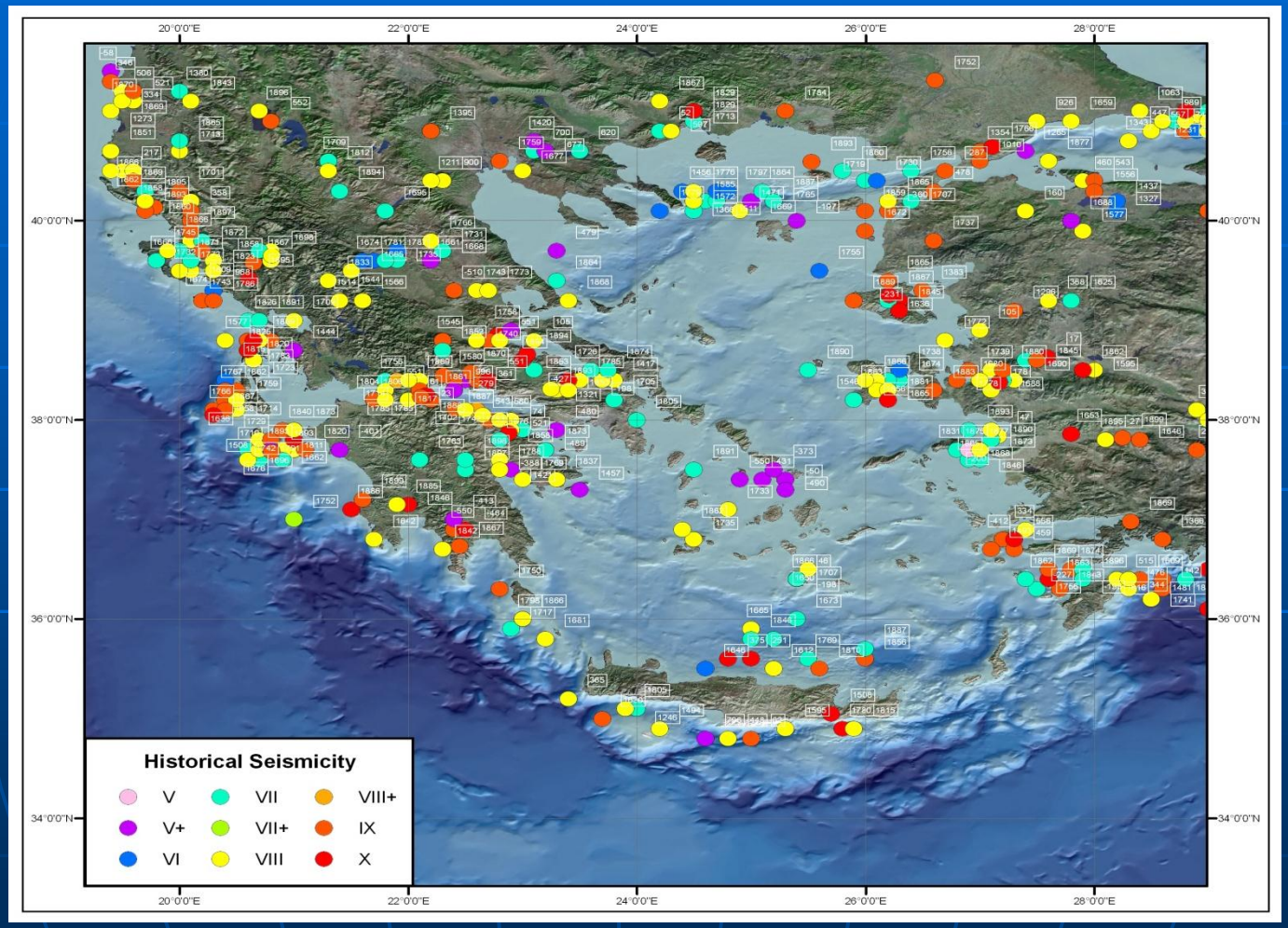
Vulnerability expresses the Seismic Response of The Monument to Seismic Event with unknown Characteristics with the degree of uncertainty in the determination of the structural Characteristics

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

Master Plan for Seismic Hazard Estimation

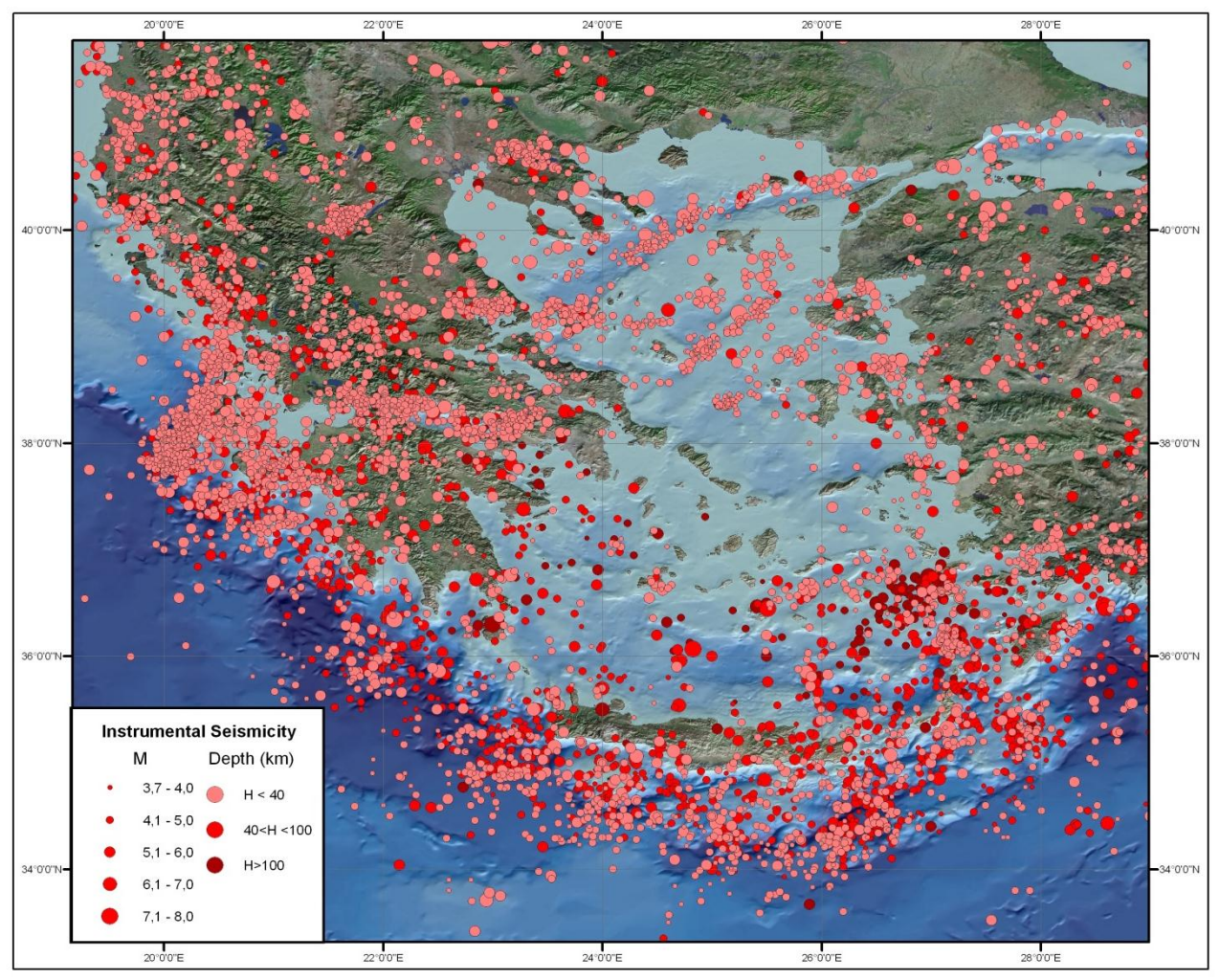
- Available data Collection
- Implementation of a GIS interface
- Joint assessment – evaluation of available information
- Monument case studies using different seismological methodologies

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE



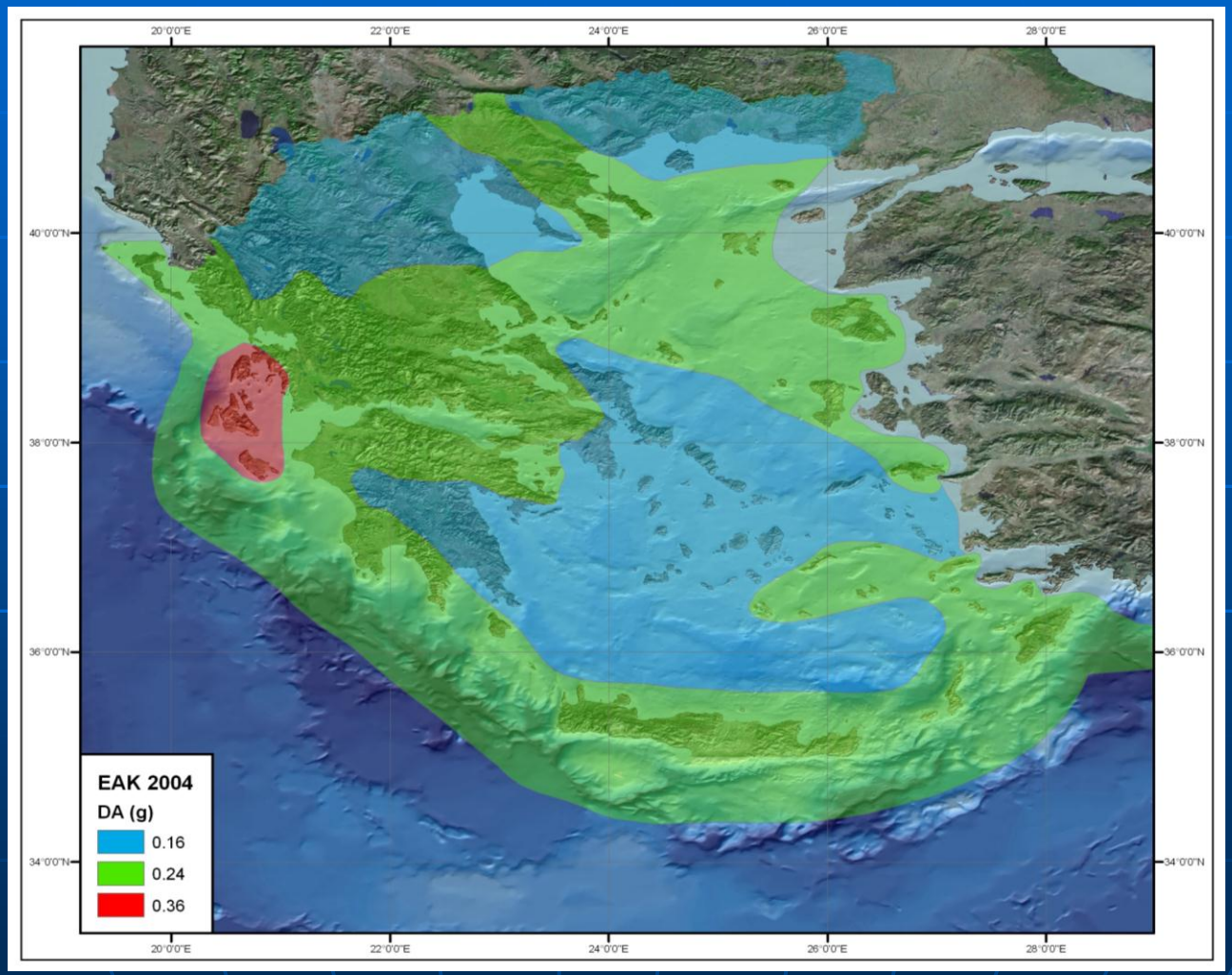
SEISMICITY IN GREECE 550 BC – 1900 AD

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE



SEISMICITY IN GREECE 1900 - 2006

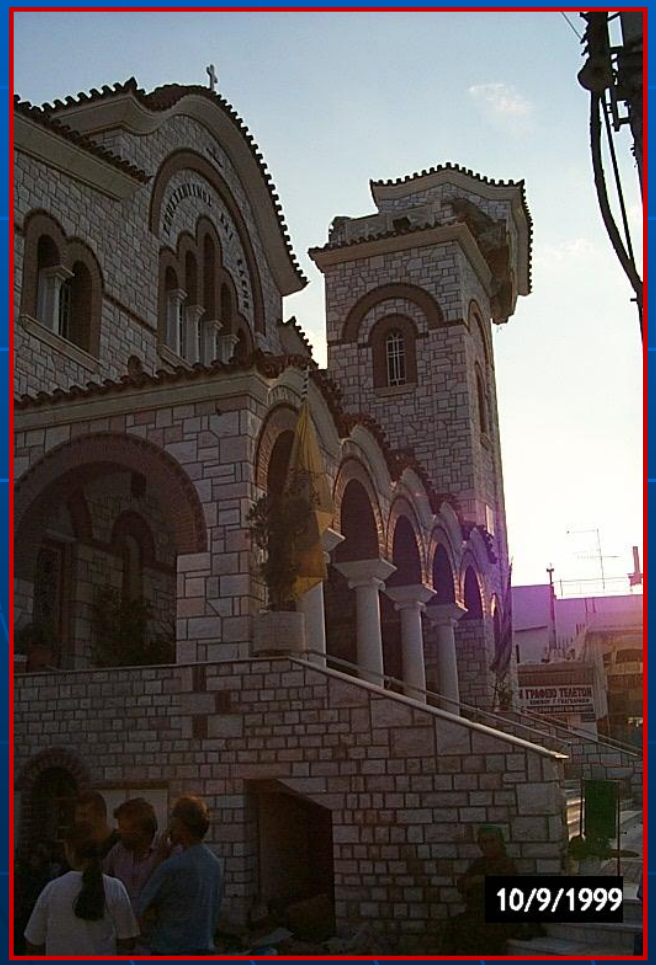
PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

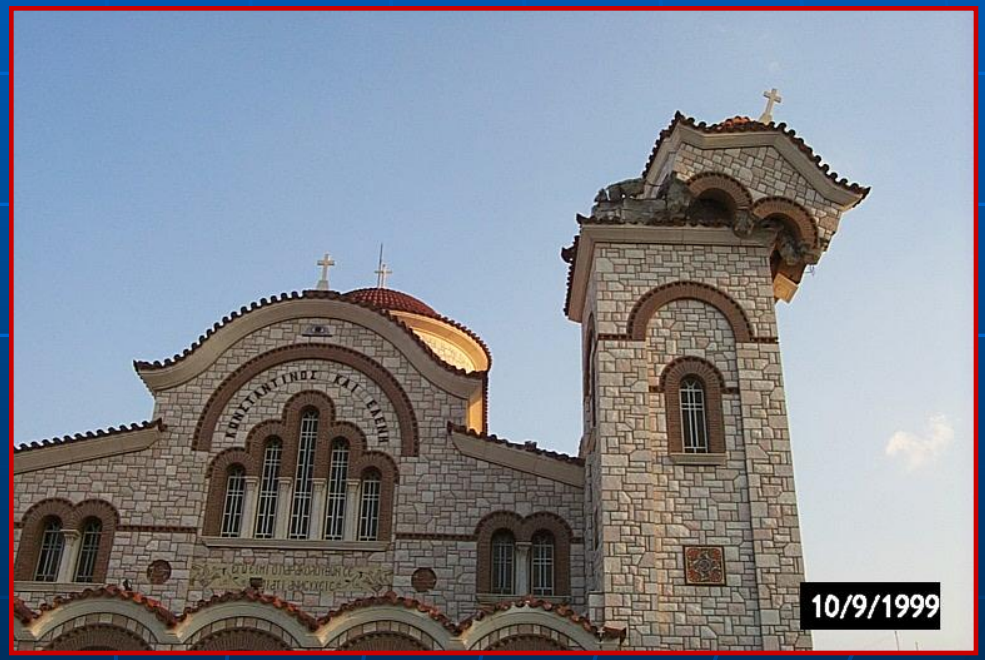


NEW SEISMIC ZONES IN GREECE

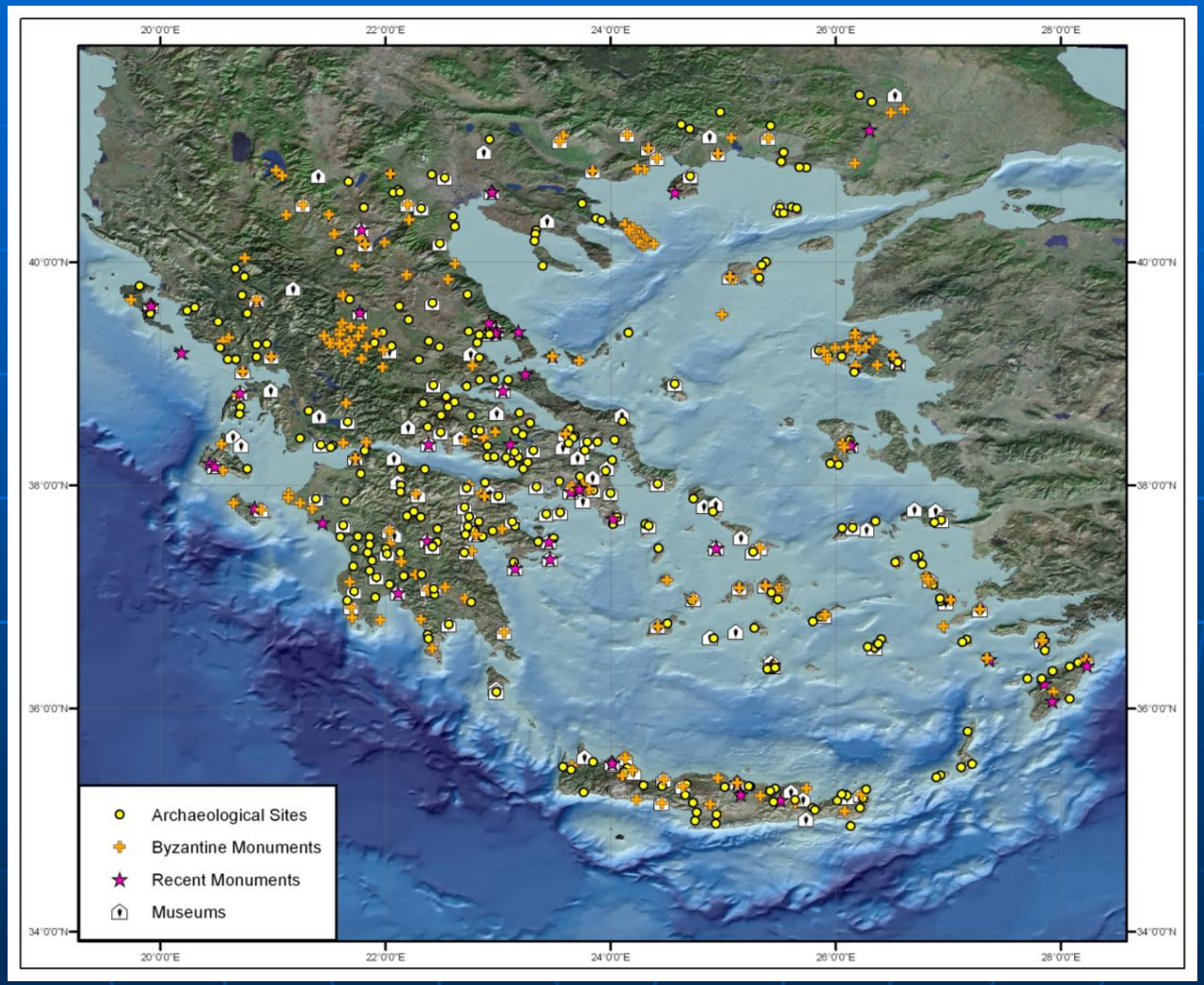
PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

ATHENS EARTHQUAKE SEPTEMBER 7, 1999



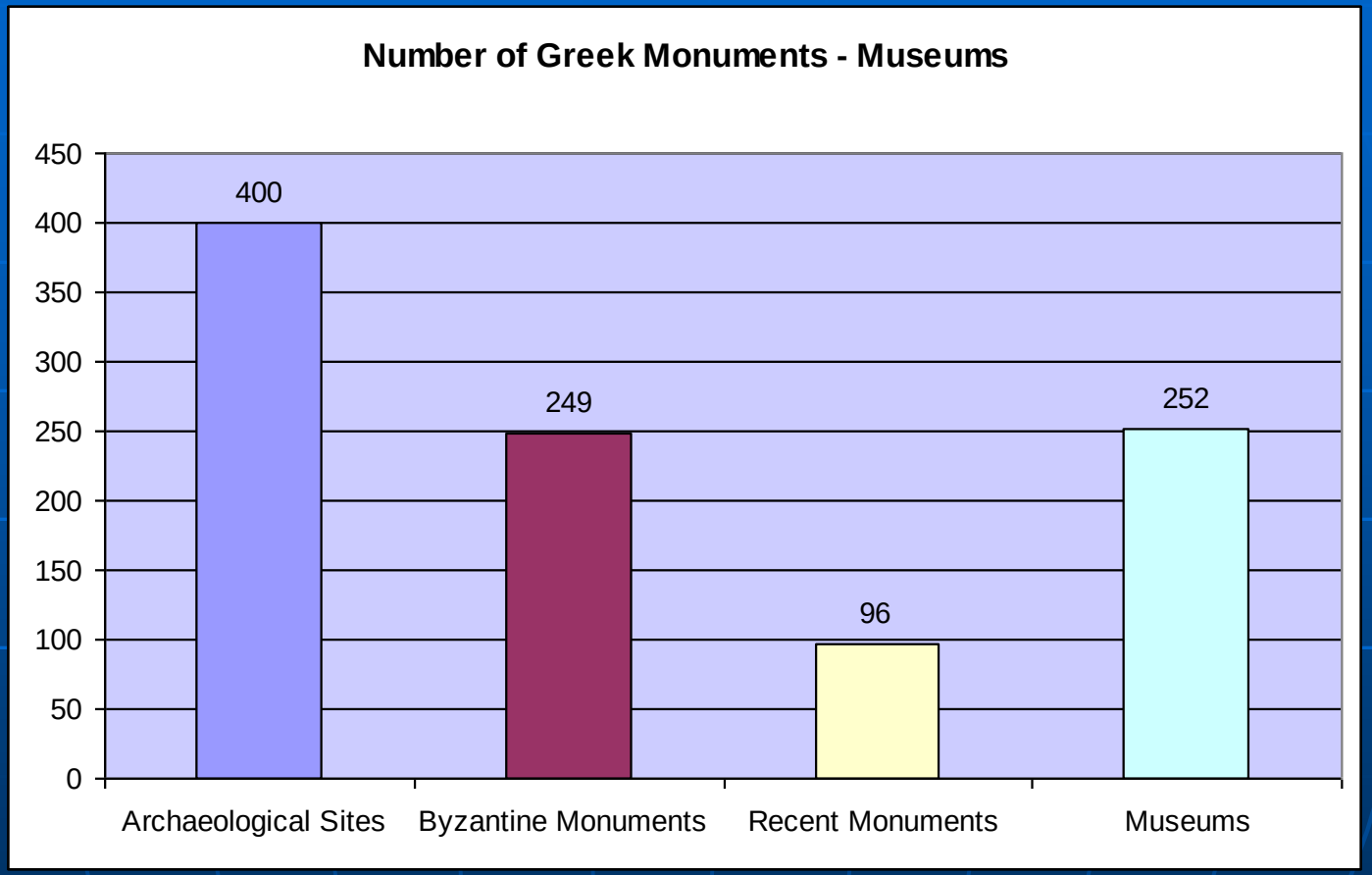


PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE



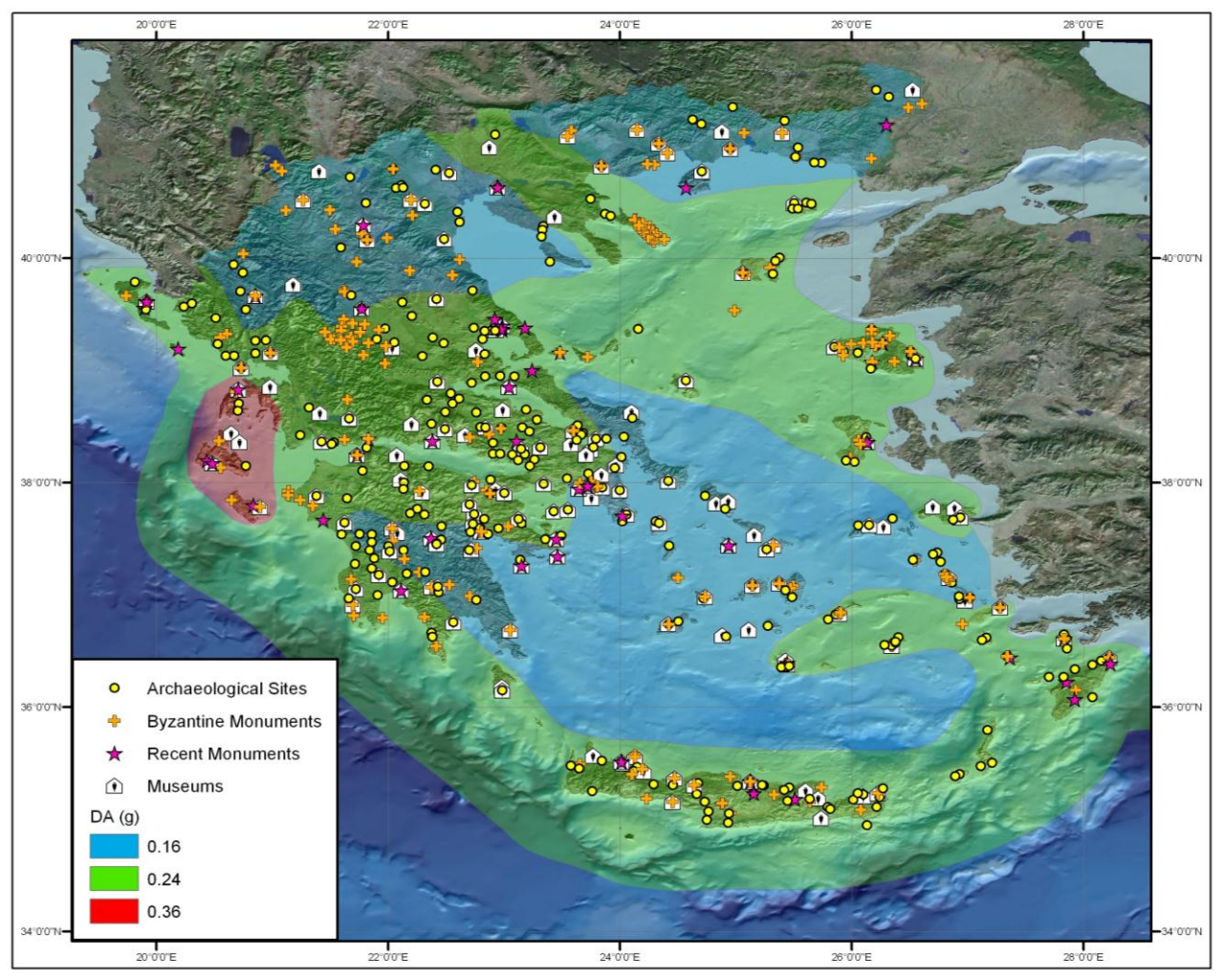
GREEK MONUMENT DATA BASE
(Source: Hellenic Ministry of Culture)

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE



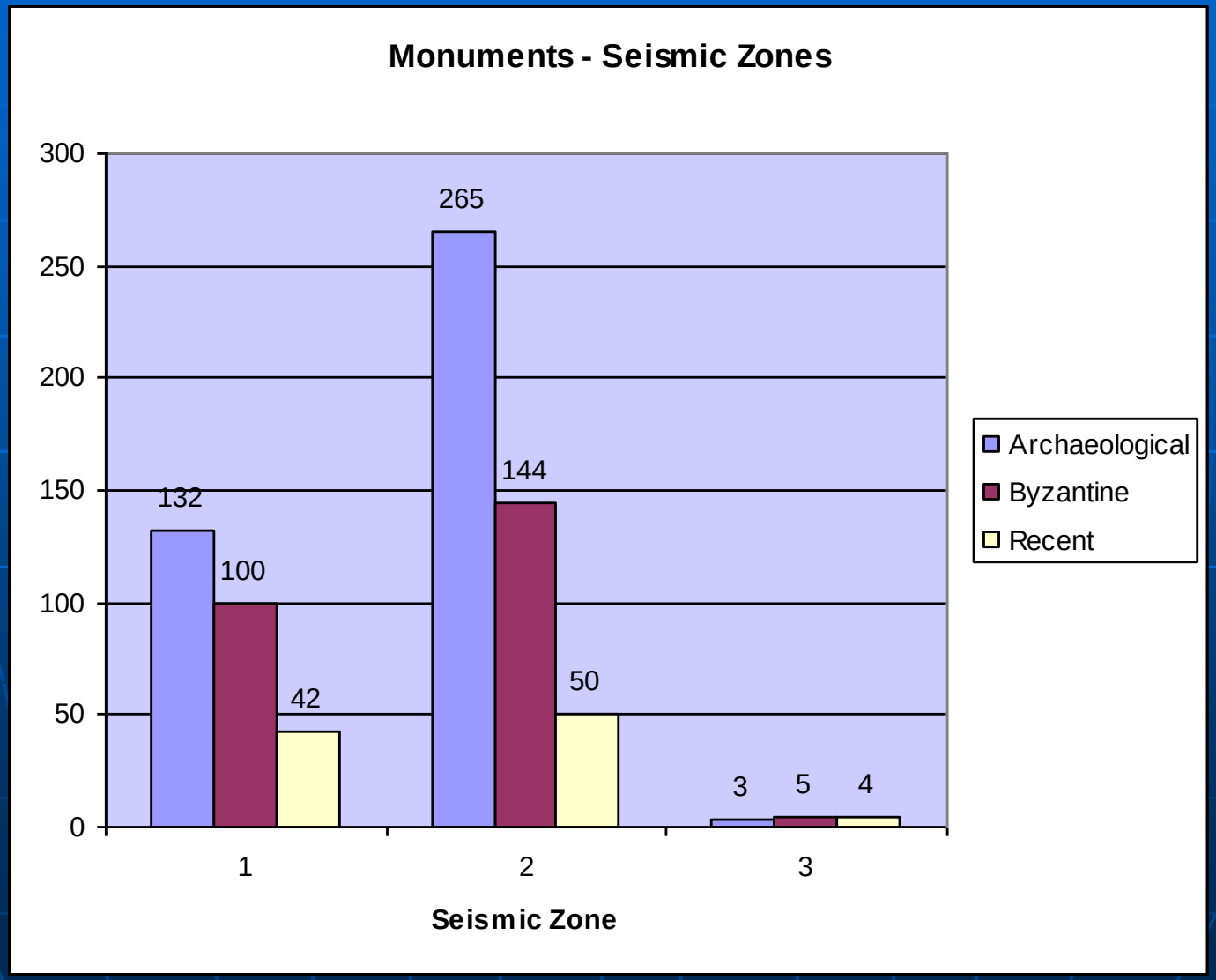
GREEK MONUMENT DATA BASE (Source: Hellenic Ministry of Culture)

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

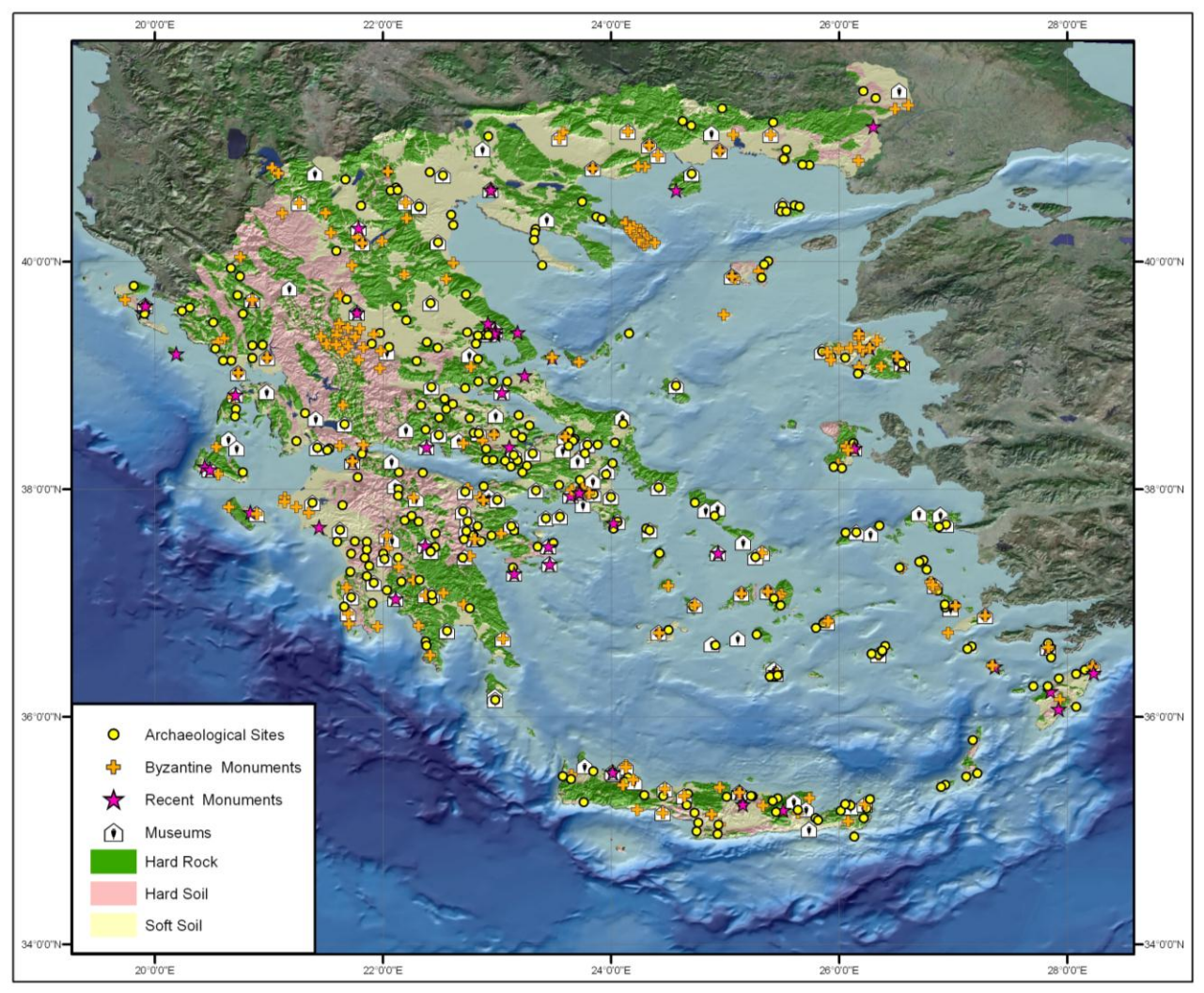


GREEK MONUMENTS - SEISMIC ZONES

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

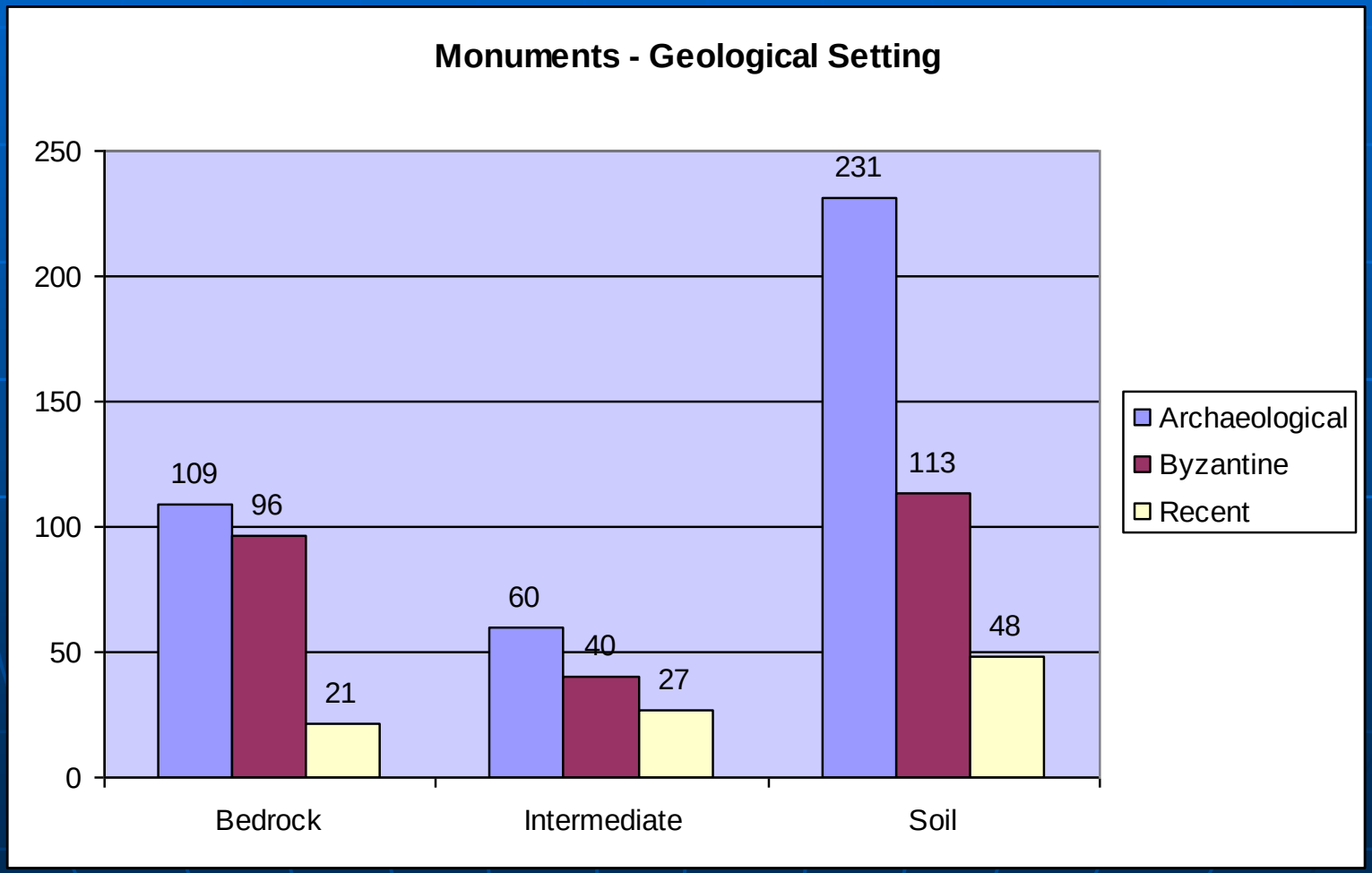


PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE



GREEK MONUMENT DATA BASE
Preliminary Site Characterization

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE



PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

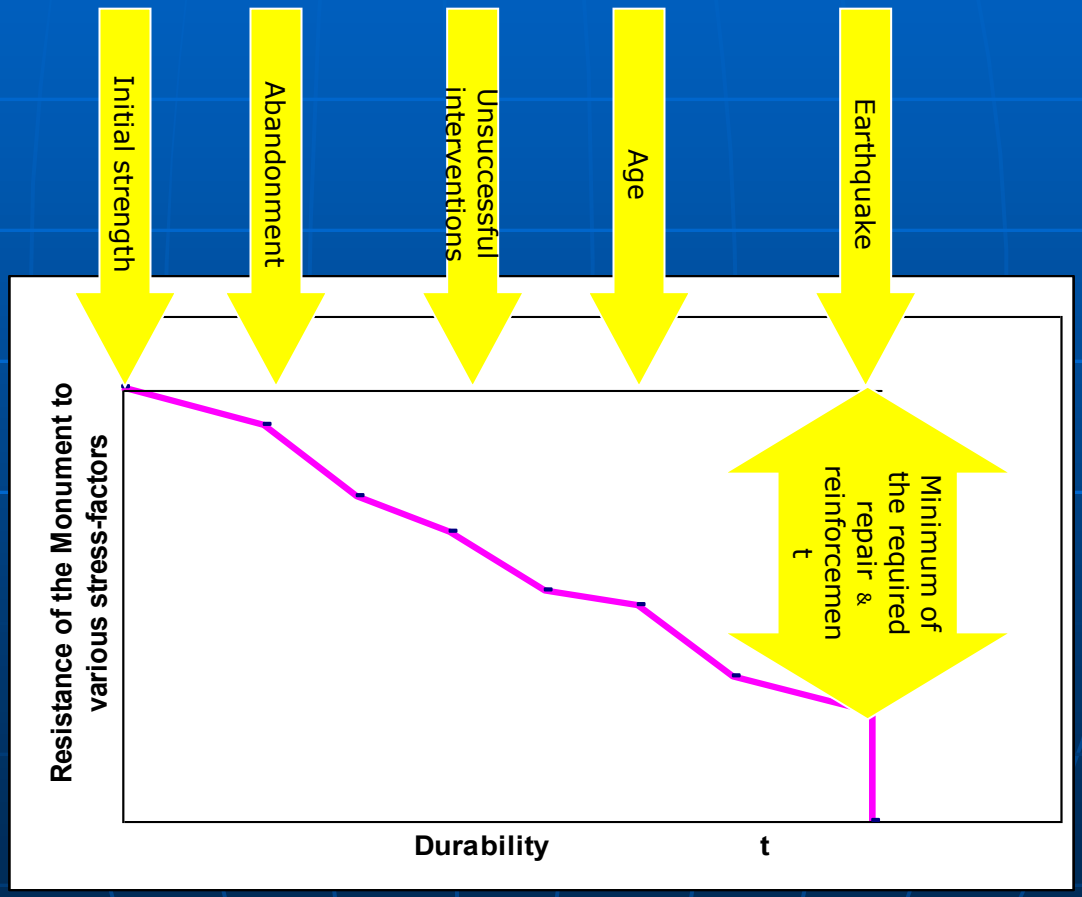
Factors that contribute to vulnerability

- Abandonment
- Unsuccessful Interventions
- Age
- Earthquake
- Natural & Chemical Damages
- Creep
- Fire
- Soil Alterations e.g. Liquefaction, Subsidence

  Underground Water, Faults e t c)
- Damp
- Air Pollution
- Tsunamis & others

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

Some of the causes leading to the weakness of the Monument



Weakness chart during time of Historical Building

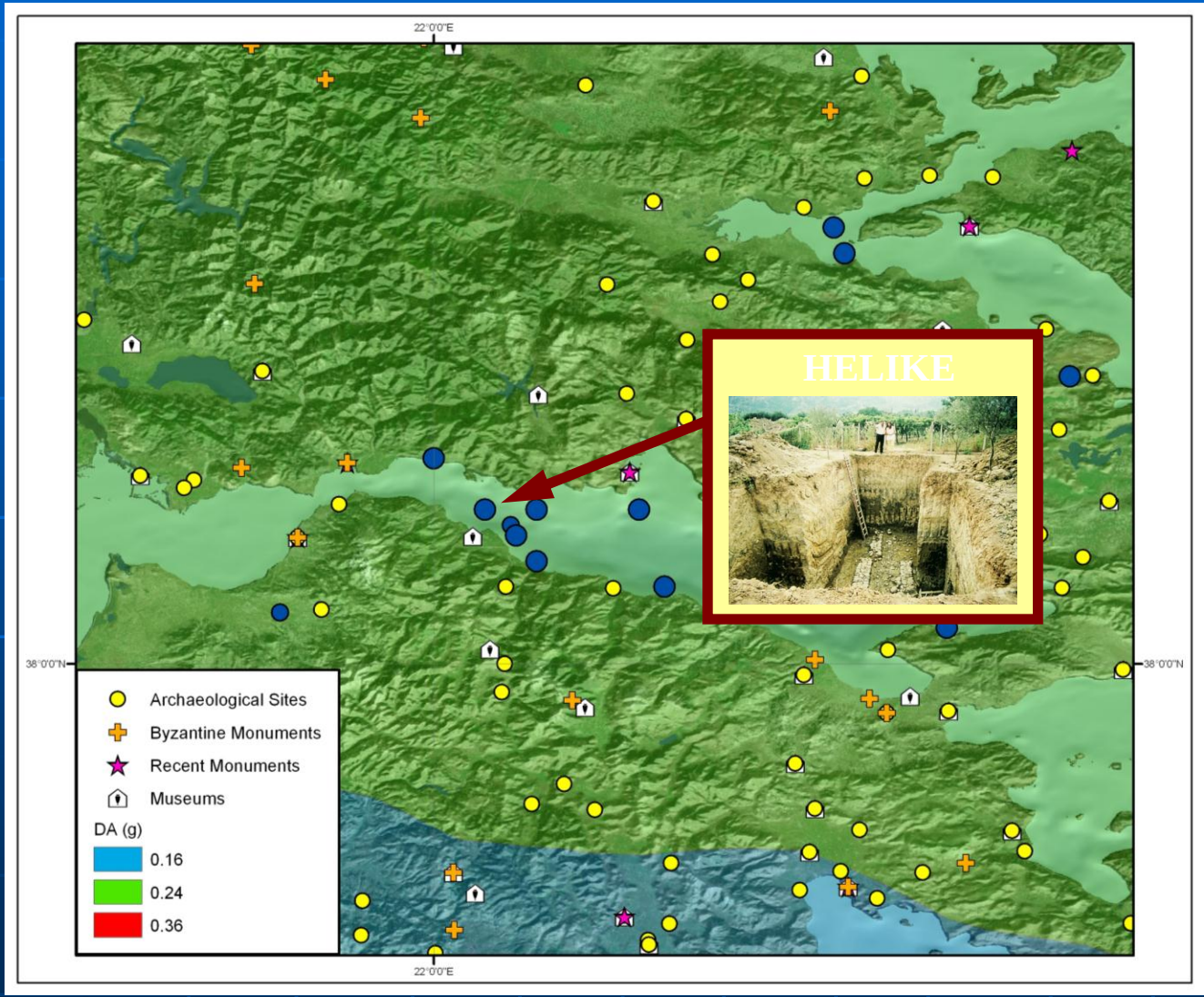
PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE - VULNERABILITY MODELS

• **Statistical** – buildings are classified by typology and other constructive details; the statistical distribution of damage grades is given by DPM (*Damage Probability Matrix*) or fragility curves; the seismic input may be in PGA or Intensity; the method is based on the observed vulnerability.

• **Mechanical-based** – the vulnerability of a set of buildings is given by a capacity curve, obtained by push-over analyses on prototype buildings; the most probable damage state is obtained by a proper comparison with the demand spectrum.

METHODS	CURRENT BUILDINGS	MONUMENTS
Statistical model	ALL BUILDINGS IN THE TOWN A methodology based on the EMS-98 classification, with a vulnerability refinement through behaviour modifiers	ALL MONUMENTS IN THE TOWN Probabilistic evaluation of the damage (fragility curves), by observed vulnerability (past earthquakes) and expertise. -
	HISTORICAL CENTRE Vulnerability of the old aggregates, due to interactions and irregularity	
Mechanical-based method	ALL BUILDINGS IN THE TOWN Simplified capacity curves for each European building type (HAZUS + new curves for European masonry, r.c., …)	MACROELEMENTS APPROACH Simplified capacity curves for some collapse mechanisms in the churches (façade overturning, triumphal arch)
	HISTORICAL CENTRE Simplified capacity curves for some collapse mechanisms, typical of historical centres (façade overturning)	MAIN MONUMENTS Capacity curves from n.l. analysis (simplified or f.e.m.)

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE



An earthquake in 373 b.c. generated a trsunami that destroyed and submerged Helike in the waters of a coastal lagoon.

In 2001, archaeologists discovered the first traces of the long-lost site of Helike, a classical Greek city buried in an alluvial plain on the southwest shores of the Gulf of Corinth.

SEISMIC ZONES - TSUNAMIS

G. Papadopoulos, 2000

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

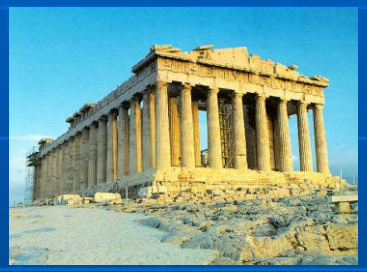
Reduction of the Vulnerability

- Short Term Measures
  - Removal of Risk Elements
  - Securing of Serviceability Levels
  - Protection against Fires
  - Post Earthquake Assessment of Monuments

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

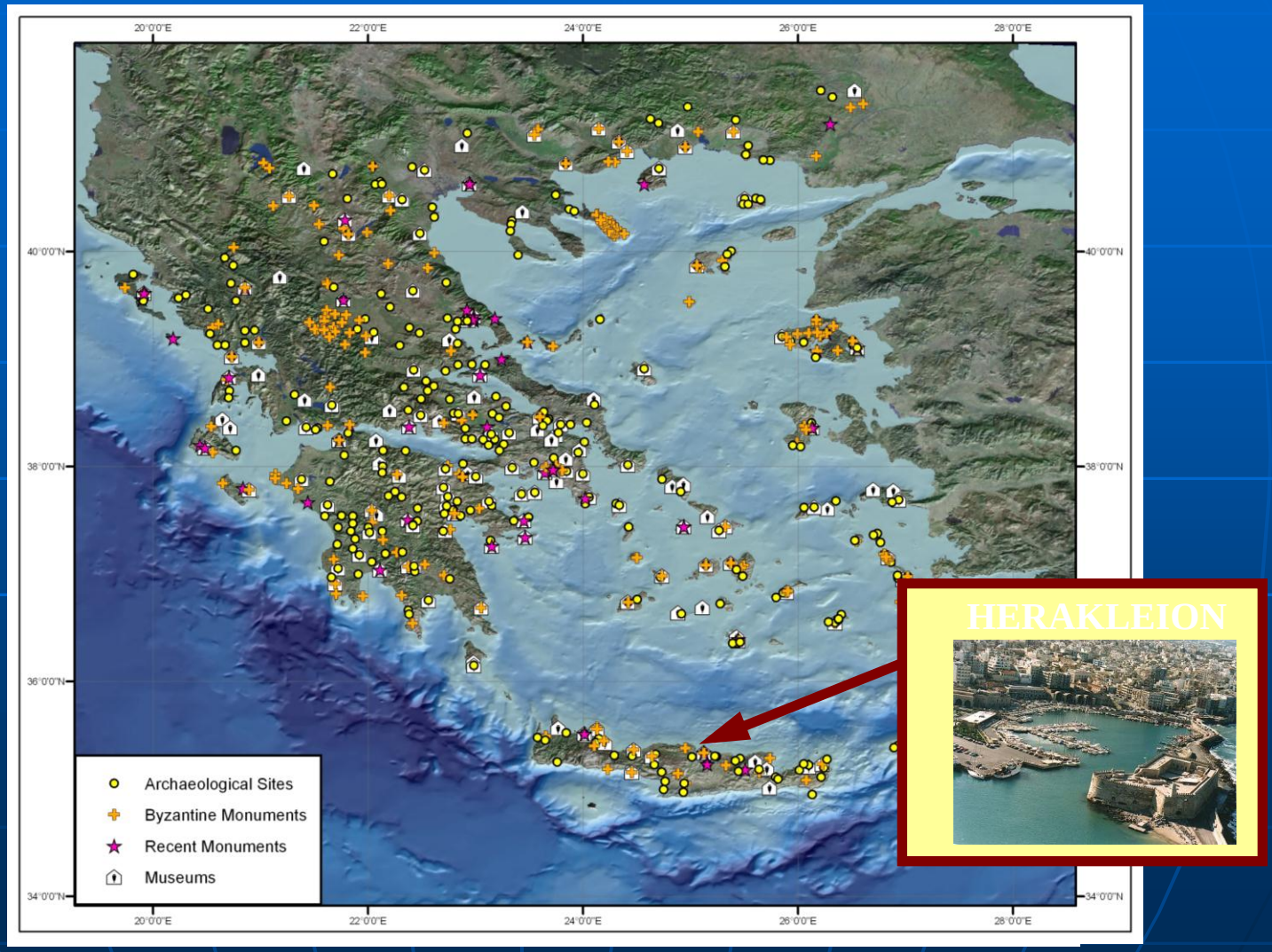
Reduction of the Vulnerability

- Long-Term Measures



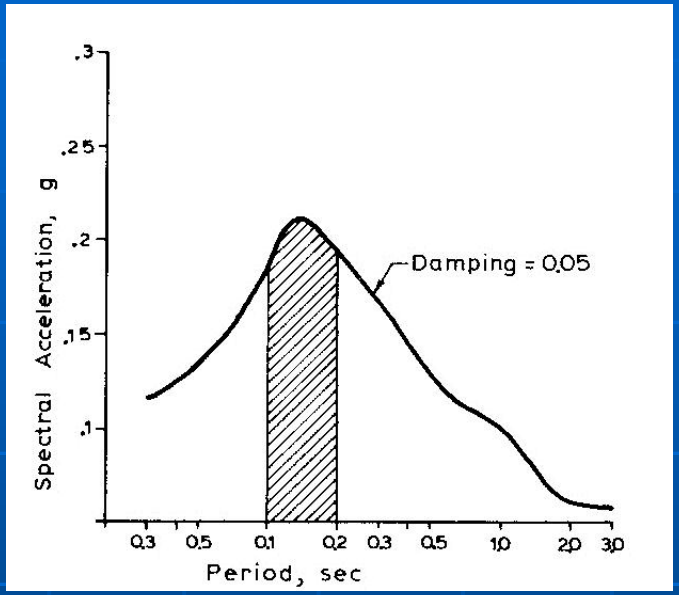
  - Syntax of the “Principles of Structural Restoration of Cultural Heritage Buildings”
  - Reinforcement of Monuments
  - Preseismic Control of Monuments
  - Monitoring
  - Examination of the A-Seismic structural Techniques of Traditional Settlements
  - Innovative Anti-seismic Techniques e.g. Seismic Isolation and Passive Energy Dissipation Systems
  - Soil Amelioration
  - Confronting of Coastal Risks e.g.Tsunamis
  - Assignment of Scientific Research Projects
  - Raising the public awareness in favour of Structural Safety of Monuments against Earthquakes

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE



Microzonation Studies: Heraklion Case

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE



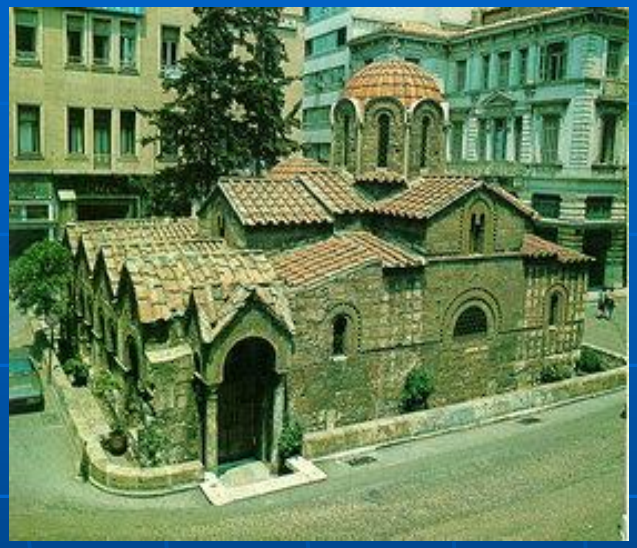
The old (first) palace was built in around 2000 B.C. but it was completely destroyed by an earthquake in 1700 B.C. The new (second) palace, more complex in plan, strongly resembling a labyrinth, was constructed immediately afterwards.

Knossos Case Study

Within the critical periods of 0.1 – 0.2 sec and with probability 90% of not being exceeded in the next 50 and 100 years, the values of spectral acceleration are found to be 0.21 and 0.24g, respectively.

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

Micro tremor Study Church of Panaghia Kapnikarea



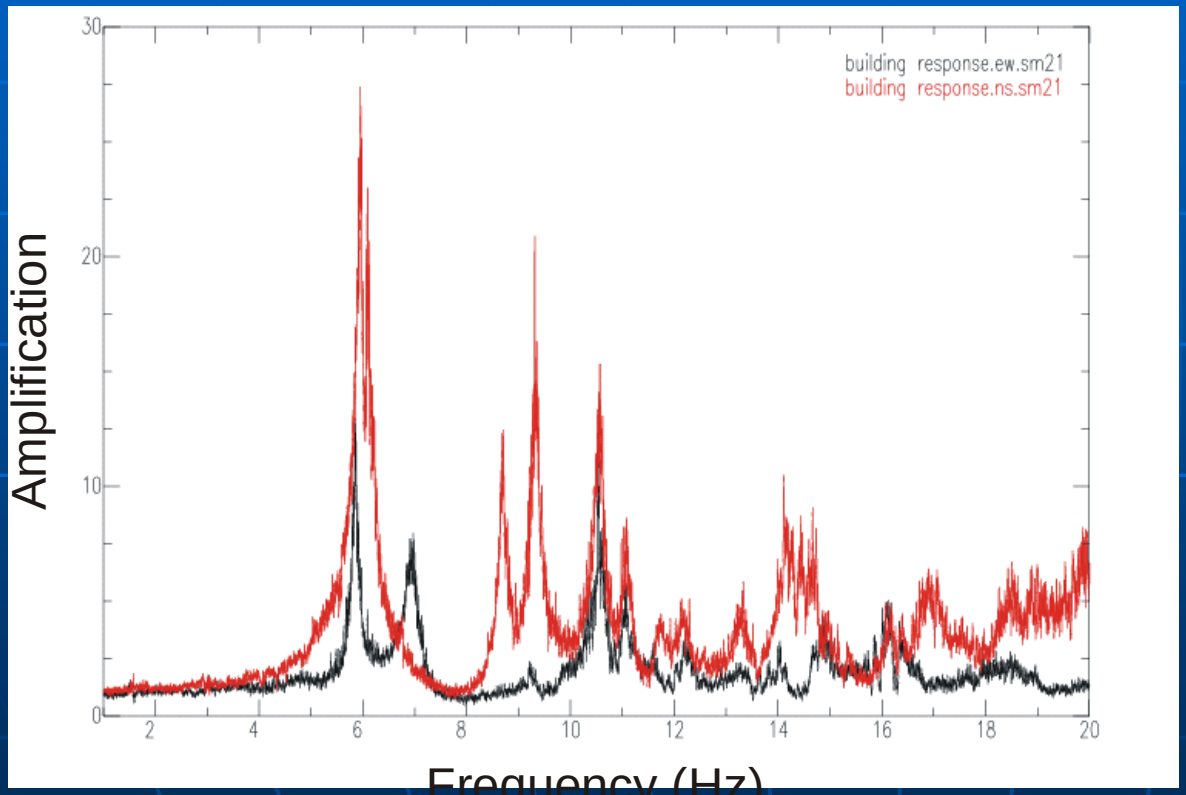
- The church of Panaghia Kapnikarea is built on the ruins of an ancient temple, dedicated to a female goddess, possibly Athena or Demeter. It was founded at the beginning of the 11th century (around 1050 A.D.) and was probably named after its donor.

- The influence of man-made seismic energy sources was examined, especially the one by the metro.

- Seismographs were installed and the dominant frequency in two dimensions was determined.

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

Smoothed Response Spectra of the Building for the two horizontal Components



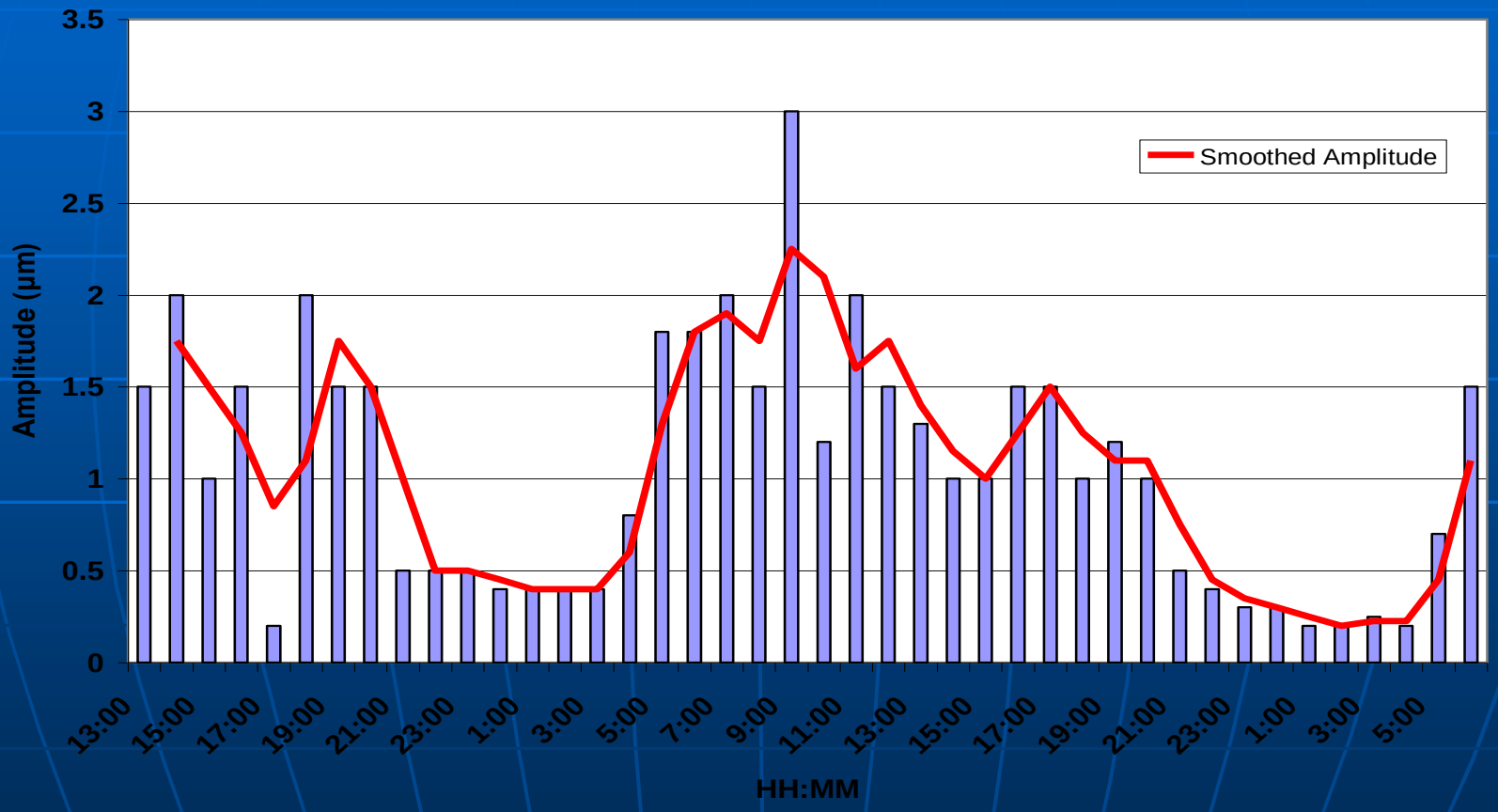
N-S:
2 peaks, 0.1-0.12 sec (8.5 – 10 Hz)

E-W:
2 peaks, 0.1 sec (10 Hz)

Maximum values are observed in both components at 0.17 sec (5.8 Hz) (Dominant Frequency of the Building).

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

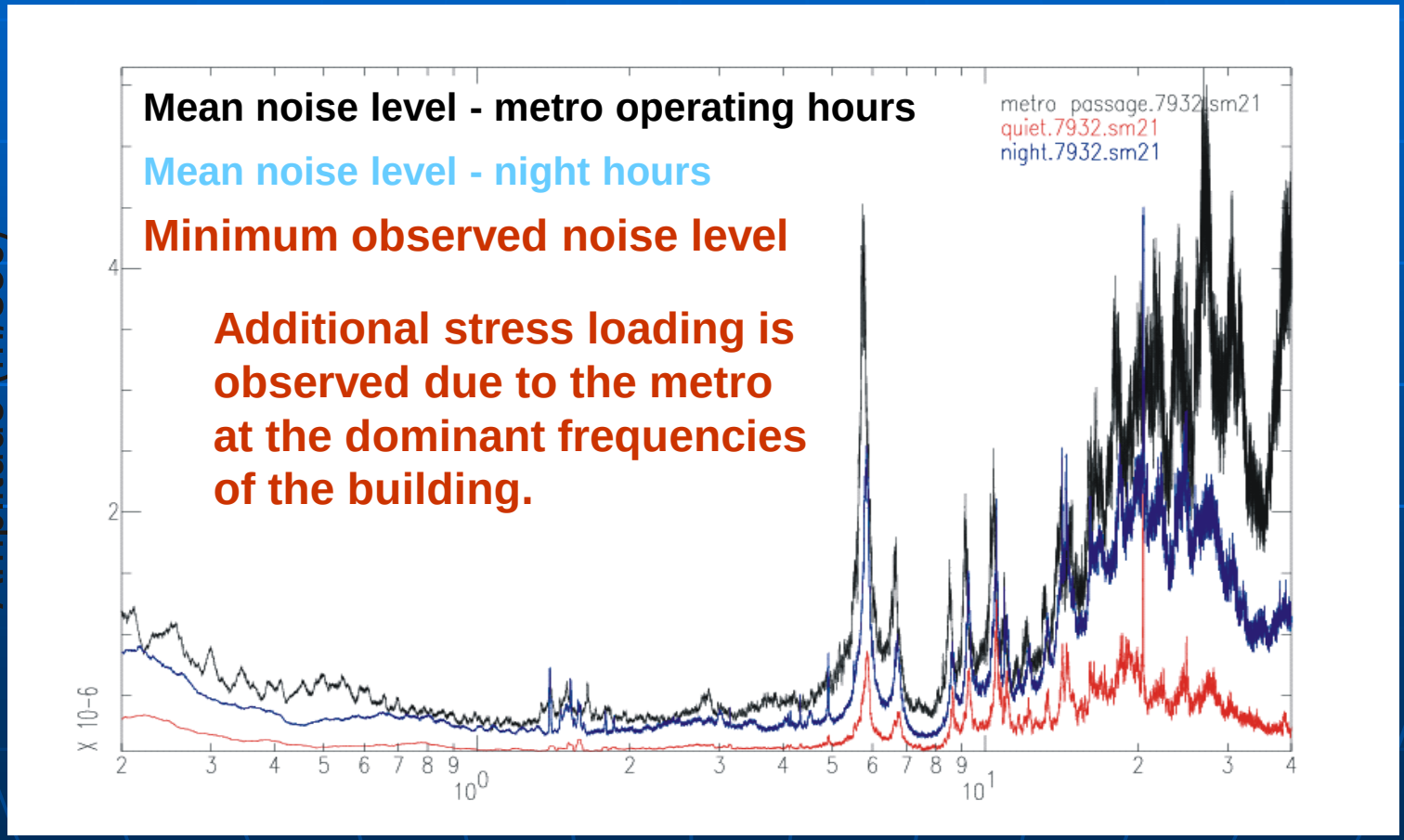
Ground Velocity Diagrams for the Dominant Period 0.17 sec (Frequency 5.8 Hz).



Increased loading during the rush hours of the metro (6 a.m. - 9 p.m.)

PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

Smoothed Amplitude Spectra (Component N-S)



PROTECTING MONUMENTS AND HISTORICAL SETTINGS FROM THE NEXT EARTHQUAKE

Seismological Studies contribute to the effort of protection of the Greek cultural Heritage and especially :

A. MONUMENT'S SEISMIC HAZARD ESTIMATION

Probabilistic and deterministic estimation of the maximum anticipated values of ground motion (acceleration, velocity and displacement).

B. MICROZONATION AROUND A MONUMENT

Ground noise analysis, geophysics, boreholes

Estimation of:

- **the influence of local geology conditions and**
- **the maximum spectral values of ground motion. The eigenperiod of the monument must significantly differ with these values, in order to avoid resonance phenomena.**

C. MONUMENT'S SEISMIC HAZARD ESTIMATION CONCERNING:

- **Tsunamis,**
- **Liquefaction phenomena,**
- **Landslides,**

caused by earthquakes.