United Nations
Educational, Scientific and
Cultural Organization

With the support of
Venice Office

National Research Council Italy

Institute of Environmental Geology
and Geoengineering Rome

Disaster Risk Management of Cultural Heritage Sites in Albania

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Disaster Risk Management of Cultural Heritage Sites in Albania

Seismological-Geohazard Risk Analysis and Disaster Risk Reduction Guidelines for Apollonia archaeological park, Historic centres of Berat and Gjirokastra and Butrint

Within the frame of the project:
"Building Capacity in Natural Risk-Preparedness
for Cultural Sites in Albania"

United Nations
ALBANIA

in collaboration with

ICCROM

UNESCO
Organizata
e Kombeve të Bashkuara
për Arsim, Shkencë dhe Kulturë

United Nations
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Cultural Organization

Komisioni Kombëtar
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Albanian National
Commission for UNESCO

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INTRODUCTION

DISASTER RISK REDUCTION (DRR) AND CULTURAL HERITAGE

The international debate concerning disaster risks has increased significantly during the last decade mainly due to the interplay of multiple factors which have worsened the severity of hazards, turning them more frequently into full fledge disasters.

Disaster vulnerability is on the rise, due to the wave of profound social environmental changes (SEC). The human agency impact has triggered profound alterations of the functions of many ecosystem services provoking amplified worldwide cascade effects. For instance, the relations between deforestation and landslides, floods and water management regimes, climate change and the sea level rise, etc, are evident. Moreover, the increased instability of the global economic system and social polarization at the global scale, leave poor population around the globe defenseless to cope with risk. Adequate mitigation strategy costs are also inaccessible to them and the impact of disasters may easily become a fatal blow to their feeble economies with long-lasting consequences.

It was the world-wide traumatic event of the Indian Ocean Tsunami in 2004 that determined the momentum necessary to set a framework of critical actions to be followed by the international community in the frame of a new International Strategy for Disaster Reduction (ISDR). UN member states recognised that they had to find new terms of commitment on Disaster Reduction. The Hyogo Declaration and Framework for Action (HFA) was therefore agreed upon (Kobe in Japan, January 2005).

The HFA five core commitments recognize that besides the need to have national plans for Disaster Risk Reduction and Management on paper, the role of education and the role of local communities and authorities are equally crucial to achieving relevant results on building societies more resilient to risks. Resilience has to be implemented on site, at the local level, building capacities and empowering communities, including those at the grassroots level. This has recently been recalled and stressed also by the Synthesis report: "Consultations on a post 2015 framework on Disaster Risk Reduction" (HFA2- April 2013) where local action underpinning community leadership and engagement in DRR is considered a key element in order to mainstream International DRR principles and guidelines into national and local agendas for action. Furthermore, the socio-cultural traditions of the natives are at the basis of risk-resilience in many parts of the world, including UNESCO designated sites, as detectable in the material constructions and buildings. Advancement of science and technology is also a main issue to be considered. The applications and products at hand today through Earth Observation, Early Warning and are potentially offering solutions which may bring invaluable benefits to local communities and to end users in the entire Disaster Risk Management cycle. However, product developers and scientists investing in cutting edge technology should find a way to effectively link and interface with policy-makers and emergency responders in particular in low income countries.

Moreover, an integrated approach is mandatory in the field of sustainable development and DRR: the traditional rift between culture and science, and the subdivisions among disciplines and fields have to be surpassed by the needs of our times.

All of these innovative impulses from HFA and the very nature of the phenomena to confront has made disaster risk preparedness an important entry point of UNESCO's strategy. UNESCO, which deals with cross-cutting issues, has mobilised all its internal resources in building upon a culture of disaster risk resilience through its constitutive components: education, science, culture and communication (Disaster Preparedness and Mitigation UNESCO's Role, 2007). In particular, UNESCO has a vital role to play in constructing a global culture of disaster preparedness and mitigation, building in the minds of people a culture of resilience to risk, promoting awareness, education and capacity and foremost a different way to approach the domain of DRR and preparedness.

UNESCO is also the secretariat of the 1972 World Heritage Convention, of which the properties have recently been the focus of substantial advancement in securing better capacity in risk management and reduction. As we know, the impact of disasters in World Heritage properties may be very significant since it could adversely affect their "Outstanding Universal Value" which justified their inscription on the World Heritage List; result in loss of lives and assets for the local people; disrupt their communities and threaten the security of visitors; negatively affect the local economy and tourism.

Since UNESCO is engaged in important actions for the protection of cultural heritage; it implements several projects in post disaster scenarios. We may historically record the following samples as internationally reckoned UNESCO post disaster operations in WHS: flooding in Florence and Venice (1966), earthquakes at the Citadel of Bam in Iran (2003) and at the temples of Prambanan in Indonesia (2006).

The World Heritage Centre (WHC) has tried to set a new course in the effort to mainstreaming capacity of reducing risk from disasters at the World Heritage properties. In particular, the World Heritage Committee adopted in 2007 a Strategy for Reducing Risks from Disasters which encourages all state parties to develop disaster risk management plans for World Heritage properties in their respective countries. In late 2010, a Resource Manual for Managing Disaster Risks for World Heritage was published. It focuses on innovative principles, methodology and process for managing disaster risks at cultural and natural World Heritage properties which are largely inspired by an inclusive and participative approach to risk. However, despite such an important conceptual advancement, disaster risk management is still at the preliminary stage among heritage professionals who need to be introduced to these new methodologies and principles.

THE PROJECT OF DISASTER RISK MANAGEMENT FOR CULTURAL HERITAGE IN ALBANIA

The UNESCO Venice Office (UNESCO Regional Bureau for Science and Culture in Europe), according to the priorities set by the government of Albania[1] and taking the opportunity offered by the One UN Programme[2], implemented the project "Natural Risk Preparedness and Mitigation - Building capacity in the field of risk mitigation for Cultural Heritage properties in Albania" during the period 2011-2013.

The project aimed to streamline disaster risk management in the Country, using its World Heritage properties as demonstration sites. The project was conceived to assist the country in order to enhance its capacity for Disasters Risk Management (DRM) and advancement in seismological and geological vulnerability of Cultural Heritage properties.

The overall context, the project objectives, its structure and results achieved in terms of capacity building and recommendations are described in the first section of this book. In this framework, UNESCO partnered with ICCROM (International Centre for the Study of the Preservation and the Restoration of Cultural Property, Rome) in collaboration with the Ministry of Culture, the General Directorate for Civil Emergencies and the Fire Corps, under the Ministry of Interior of Albania, the management authority of National Heritage, the regional departments of Archaeological Parks of Apollonia, Berat, Butrint and Gjirokastra, and the Albanian National Commission for UNESCO.

PART I - CAPACITY BUILDING, RISK ANALYSIS AND GUIDELINES ELABORATION

This activity was conducted in cooperation with ICCROM, by designing and implementing an intensive training on Disaster Risk Preparedness and Management at the World Heritage site of Berat in Albania from 19 to 24 November 2011. This brought together heritage professionals from the selected major heritage sites of Albania (Butrint, Berat-Gjirokastra and the archeological park of Apollonia) and civil emergency responders. It successfully provided them with knowledge on current thinking, methods and tools available for the preparation of Disaster Risk Management plans on the basis of the World Heritage Resource Manual on "Managing Disaster Risks for World Heritage"[3].

Using the manual and analyzing the specific context of the selected sites, a broader methodological framework was developed. This was done to lay the ground for the development of disaster risk management plans in the selected cultural sites, acting as a model for other sites both in Albania and in the entire Region. The workshop was timely conceived since overall World Heritage properties' management plans are currently under development in Albania[4]. Special focus was devoted to risk preparedness for earthquakes and fires, through the participation of highly qualified international experts on such fields of expertise.

Trainees were also provided with a post-training coaching support and have obtained personal certificates of attendance upon delivery of a site-based framework presentation highlighting all relevant components for their future management plans. Their outputs which are presented in the ANNEX I of the PART I of this publication, were presented along with the CNR-IGAG report, at the final workshop of the project "Disaster Risk Preparedness and Management in Cultural Heritage Sites" held at the WHS of Berat, 8 May 2012, organized in cooperation with the EU-funded project SUSTCULT. The workshop showed local stakeholders and representatives of the Cultural sites (among which UNESCO designated sites in South East Europe) how an integrated approach inclusive of risk is necessary for a good management of World Heritage sites.

The Risk Analysis of natural hazards and the guidelines for the risk reduction of Cultural Heritage in Albania (chapters 3 and 4) were elaborate by the experts considering the contribute of the local managers and element/data collected in the World Heritage sites visited.

The conference was followed by a "site by site" visit of UNESCO-ICCROM team at the World Heritage sites of Gjirokastra/Berat and Butrint. This was on one hand conceived in order to secure a post-training coaching support to the heritage and civil protection professionals, useful to help their efforts in devising new management plans for their sites. On the other it provided first-hand knowledge of the most felt risk in the sites upon which the guidelines at PART I (chapter 1) have been developed.

PART II - SCIENCE-BASED SEISMOLOGICAL AND GEO-VULNERABILITIES MAPPING

This activity was done by the launching of a microzonation assessment of level 1[5] at the World Heritage properties of Gjirokastra, Berat, Saranda-Butrint and the Apollonia archaeological park. An interdisciplinary Italian/Albanian work team composed of engineers, geologists and archeologists led by CNR (Centro Nazionale Ricerche) - IGAG (Istituto di Geologia Ambientale e Geoingegneria) started a specific geological and geophysical field survey based on micro-zonation in late November 2011. This produced a comprehensive assessment report and related maps of Seismological Risk and Geo-hazard Vulnerability based on the first level of investigation, in the above-mentioned selected sites which is duly reported in PART II, chapter by chapter from 1 to 7 with the inclusion of a dedicated part (chapter 8) on the methodology adopted for the geophysical investigation.

The policy impact on risk may prove highly relevant as reliable scientific data should provide crucial support to the decision makers on geo-risk management in UNESCO designated sites. The produced data is, in fact, considered very sensitive among designated sites managers to adequately tailor actions according to the magnitude and nature of the risk(s) at stake. It represents a tool for site managers and planners in Albania, bringing out evidence-based findings and providing useful information for:

- Establishing guidelines and criteria of interventions in urban areas and cultural sites.
- defining priorities for interventions.

Finally, the work was framed into an interactive relationship with site managers and integrated into the activities of capacity building performed in the field of DRM under the same project (see point 1 above), in order to develop appropriate risk management systems, including management guidelines and action plans for the cultural sites, along with particular provisions to improve ordinary maintenance, retrofitting of existing infrastructures or monuments, enlarge buffer areas, etc. (prevention/mitigation- emergency preparedness Phase).

It is hoped that, despite heavy budget cuts which have impaired the continuation of these project activities in Albania, this project has offered a valuable technical support both to site managers and to emergency responders, meeting the growth of demand for Disaster Risk Reduction in South East Europe.

It is foremost hoped to have successfully delivered a message that DRR in Cultural heritage sites is not for human or natural sciences, for technological applications and investigations, for emergency responders or site managers, for ministries and departments as individual actors but for all of them in an inclusive and integrated way since their bond improves risk resilience.

NOTES

[1] The most relevant natural hazard risks for Albania include earthquakes, floods and fires. Based on existing knowledge the project aims at assisting Albania in improving its capacity to prepare for seismologic risk and to mitigate possible effects on its Cultural Heritage, as elements of a more general strategy to reduce the impact of climate change effects as well as to reduce man induced effects causing natural disasters.

[2] In 2007, the UN Secretary General launched ONE UN initiative. Albania was amongst seven countries that volunteered to become a testing ground for the implementation of a reformed UN system.

[3] http://whc.unesco.org/en/activities/630

[4] World Heritage Sites Management Systems have been strongly encouraged since the 1990s and an included requisite in 2005 Operational Guidelines for the Implementation of the World Heritage Convention.

[5] The seismic microzonation map of level 1 identifies the geometry of microzones potentially characterized by specific seismic effects. The maps, in particular, define the microzones where likely are the occurrence of different types of seismic effects such as local amplifications, slope instability, differential settlement, liquefaction, on the basis of geological and geomorphological observations and assessment of available lithostratigraphic data.

PART I

NATURAL DISASTER RISK PREPAREDNESS AND MITIGATION GUIDELINES OF CULTURAL HERITAGE SITES OF ALBANIA

1. PROJECT OVERVIEW: MOTIVATIONS, OBJECTIVES AND STRUCTURE

"This training changed my perception, I see things differently now, I am more conscious and aware of risks, I can spot them where once I could not".[1]

As recalled in the recent Heritage and Resilience Publication prepared for the fourth session of the global platform for Disaster Risk Reduction (19/23 May 2013) in Geneva, Switzerland (R. Jigyasu, 2013), the recommendations of the WHC in 2007 on Reducing Risks from Disasters that encourage all states parties to develop disaster risk management plans for the World Heritage properties under their sovereign jurisdiction, have been largely disregarded.

Several indicators corroborate this assertion, such as the very low numbers of requests submitted in the frame of the WH International Assistance Programme that concern disaster risks and a WHC survey on the role of WHS managers and managing authorities of sites, mainly placed in high-risk locations, to DRR. As reported, only one out of 10 investigated sites have formally complied with the above recommendations (Fig. 1; P. Antoniu, 2012). There is also evidence of the fact that poor or no risk reduction elements are particularly traceable in WHS management systems located in low-income countries.

This projection may also be applied to south eastern European countries, in particular to those of lower-middle income such as Albania,[1] which still ranks as one of the poorest countries in Europe, despite undisputed progress made after the collapse of its communist regime.

Taking the opportunity offered by the integrated project on Disaster Risk Preparedness in Cultural Sites of Albania under the ONE UN initiative, and foremost in consideration of the fact that Albania is vulnerable to several types of hazards including structural fires, wild land fires, earthquakes, floods, heavy storms, rock falls and landslides and in accordance with the government of Albania priorities, the implemented actions

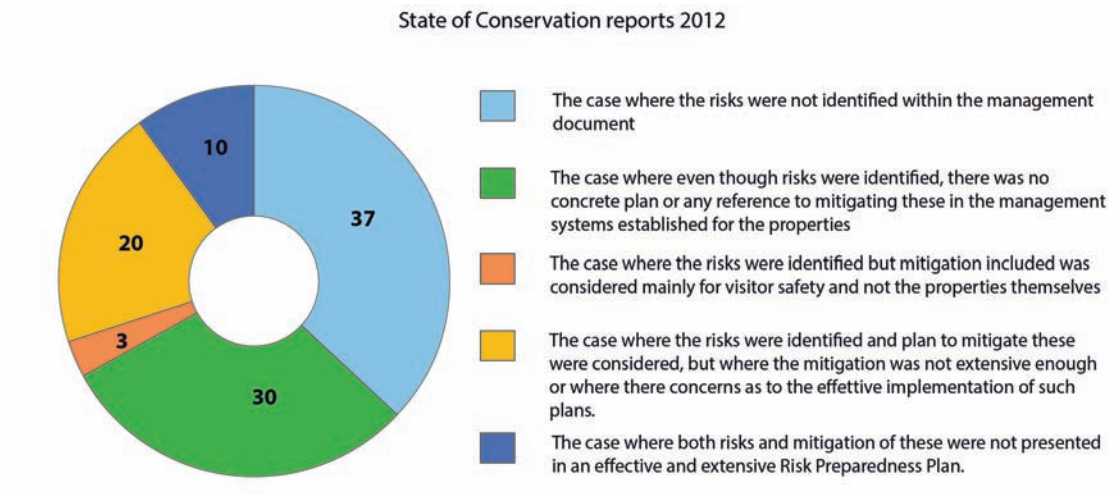

Fig. 1. Analysis of responses as per the State of Conservation Reports 2012. Based on the study by Pinelopi Antoniou for UNESCO World Heritage Centre 2012. The graphic should be considered as an indicative projection since not comprehensive of all WHS.The graphic should be considered as an indicative projection since not comprehensive of all WHS.

NOTE
[1] Statement of trainee at the end of UNESCO-ICCROM Training, Berat, November 2011.

were conceived to compound the scientific investigations conducted to assess the geohazard vulnerability of the major cultural sites of Albania with the need developing the governance capacity of the targeted sites in Disaster Risk Reduction.

In more details the UNESCO Venice Office and ICCROM pioneered a training workshop on Disaster Risk Preparedness and Management at the World Heritage site of Berat (19 to 24 November 2011; Fig. 2 a,b). This brought together heritage professionals from the aforementioned selected World Heritage properties of Albania and provided them with knowledge on current thinking, methods and tools available for the preparation of Disaster Risk Management plans on the basis of the newly issued World Heritage Resource Manual on "Managing Disaster Risks for World Heritage" (http://whc.unesco.org/en/activities/630/).

Using the manual and analyzing the specific context of the selected sites, a broader methodological framework was developed. This was done to lay the ground for the development of Disaster Risk Management plans in the selected cultural sites, acting as a model for other sites both in Albania and in the whole region.

This action was therefore designed, planned and conducted in close collaboration with ICCROM and the World Heritage Centre. Its objectives were meant to illustrate the core principles of Disaster Risk Management (DMR) for Heritage Sites and the applied methodology to identify, assess and mitigate disaster risk in Cultural Heritage sites. This was performed by:

- Training key stakeholders and site managers selected in collaboration with the government of Albania, to reduce risks in their cultural heritage properties;
- Teaching in a demonstrative way how to prepare a DRM plan for cultural heritage properties.

The Disaster Risk Reduction (DRR) training was conducted in a timely manner as it coincided with the development of the Disaster Risk Management (DRM) plans for three World Heritage Site in Albania, in Berat, Butrint and Gjirokastra. Special focus was devoted to risk preparedness for earthquakes and fires[2], through the participation of highly qualified international experts on such fields of expertise.

Trainees relied on post-training coaching support from these experts and received personal certificates of attendance upon delivery of a site-based framework presentation highlighting relevant components for their future management plan (15th May 2012). The benefits of the seeds sown throughout the short and intensive training and coaching activities produced a lasting legacy that saw DRR principles and concepts integrated into the DRM plan for Berat. Projects in Butrint and Gjirokastra now have the capacity to also follow this example of good practices. As a general rule and stressed by prominent scholars and practitioners in the field, for institutional arrangements set in place for managing the commons or, as in our case, to mainstream DRR principles, there is a vast distinction between 'rules on paper' and 'rules in practice' (Ostrom, 1990). The real threshold between the success and failure of a system of governance (regimes) lies in their level of effectiveness. This depends on whether the regime is translated by the social constituents (main stakeholders) into everyday practices or whether the plan is merely fed into 'dead letter documents' and not utilized

Moreover, whether formalised or not, the importance and effectiveness of management plans are dependent on their capacity to embody guiding DRR principles within the overall management system(s) in force. This step is fundamental to ensure the resilience of heritage sites against disasters and unforeseen events and also against potential risks to the site's authenticity, integrity and their outstanding universal value.

Taken as a whole, a DRR management plan should be considered as a continuous cycle of an ongoing process of revision and change with inputs from monitoring and evaluation mechanisms followed by subsequent implementations of further action. This process is rather unique to the DRM cycle, which is characterized by constitutive and interconnected phases of identification and assessment of risk, prevention and mitigation, emergency preparedness and response, and recovery actions, whenever required.

Whilst the DRR cycle in its entirety was introduced and analyzed throughout the DRR training held in Berat, the scope and purpose of the current chapter is to report on the concrete outcomes of the workshop whereby the first phase of the DRM cycle, that is, the identification and assessment of risk phase was done. This first step of the DRM cycle is fundamental to the process, and will pave the way for further phases to be implemented.

To conclude, it is within our best interests and under our auspices that further activities that mirror the success of the initial stages of capacity building and the integration of DRR principles into the management plans for Berat, will be realized and implemented for World Heritage Sites throughout Albania. The intention of such a process is to provide site managers and heritage administrators throughout countries in South East Europe with an effective methodological framework to make World Heritage Sites more resilient to risk at the global level.

The following is a brief overview of the three Cultural Heritage sites with World Heritage status, in Albania: Berat, Butrint and Gjirokastra, the various risks each faces, and risk prioritization recommendations to begin addressing these risks.

a

b

c

d

Fig. 2. Photo at Training Workshop on Disaster Risk Preparedness and Management at the World Heritage site of Berat (19 to 24 November 2011) (a,b); c) painting at the churches of St. Mary of Blachernae; d) churches of the Holy Trinity.

2. ALBANIAN WORLD HERITAGE SITES

The city of Berat

The city of Berat was inscribed with Gjirokastra in the World Heritage list under the appellate of Historic Centres of Berat and Gjirokastra in 2008. They were inscribed on the basis of criteria (iii) and (iv) as per Decisions 29 COM 8B.48 and 32 COM 8B.56.

Criterion (iii): Berat and Gjirokastra bear outstanding testimony to the diversity of urban societies in the Balkans, and to longstanding ways of life, which have today almost vanished. The town planning and housing of Gjirokastra are those of a citadel town built by notable landowners whose interests were directly linked to those of the central power. Berat bears the imprint of a more independent life-style, linked to its handicraft and merchant functions.

Criterion (iv): Together, the two towns of Gjirokastra and Berat bear outstanding testimony to various types of monument and vernacular urban housing during the Classical Ottoman period, in continuity with the various Medieval cultures which preceded it, and in a state of peaceful coexistence with a large Christian minority, particularly in Berat.

Located in central Albania, Berat bears witness to the peaceful coexistence of various religious and cultural communities through the centuries. It features a castle, locally known as the "Kala", most of which was built in the 13th century, although its origins date back to the 4th century B.C. The citadel area has many Byzantine churches, mainly from the 13$^{th.}$century, as well as several mosques built under the Ottoman period. The city is comprised of urban quarters dated to the15th through19th century.

The settlement is traditionally believed to have been founded by Cassander, King of Macedonia, in 314 B.C. and later ended up under the Roman protectorate.

Excavations around the medieval city walls of Berat have resulted in the identification of parts of the first wall circuit, including the remains of a major gateway. These wall sections date to the 4th century B.C. (Braka, 1990).

The findings from the excavations within Berat date back to the 7th century B.C., which suggests that the city of Antipatrea was possibly established on an existing Illyrian settlement.

In 440 A.D., the city was renamed Pulcheropolis by Emperor Theodosius II (408-450 A.D.) after his sister. Later the city walls were rebuilt, most probably during the reign of the Emperor Justinian (527-565 A.D.).

In the 9th century *Pulcheropolis* fell to the Bulgars. The city was renamed Belgrade (from which the modern name of Berat derives) and was the seat of a bishopric. The Bulgars lost the city in the 11th century to the Byzantine Empire. Under the Despotate, the Muzaka family dominated Berat.

The city was refortified in the 13th century. The city walls were rebuilt, following the contours of the hill, to form a triangular fortress, enclosing 9.6 hectares. The city walls were protected by a system of towers. Within the city, a castle was constructed on the summit of the hill. It comprised an outer work, five towers and an inner work with a large cistern. Alterations and additions were made to the system of fortifications throughout the following century, and included an extension of the fortified area by the construction of two defensive walls (Fig. 2c) running from the south side of the city wall to the river. This extension enclosed a further six hectares. Several churches dating to the 13th and 14th centuries have survived within the city - the churches of St. George, St. Michael and the Holy Trinity being the best preserved (Fig. 2 d,e).

In 1417, Berat fell under Ottoman control. The fortifications were maintained with the addition of urban quarters at Gorica and Mangalem, outside the medieval fortifications. The city prospered under the Ottomans and much of the historic centre of modern Berat comprises Ottoman-period houses (fine 17th and 18th century stone-built dwellings) and, close to the river, timber-framed shops of the old bazaar. In addition there is an important group of mosques including the late 15th century Sultan's Mosque (*X*hamija e Mbretit), the 16th century Leaded Mosque (Xhamija e Plumbit) and the 19th century Mosque of the Bachelors (Xhamija e Beqareve). A group of 18th century buildings associated with the Tekke of the Helvetis also has survived. Many churches were also constructed in this period and decorated by Onufre, a 16th century Albanian painter, and his school of painters. A museum of Onufre's work can be found in Berat.

Threats to the World Heritage Property of Berat

Since the time of its inscription, the site has recorded a combination of human- and natural-induced threats, affecting the property:

Natural

- seismic threat
- fires
- floods
- landslides, rock falls

Human

- lack of specific monitoring indicators
- lack of a program of archaeological excavations
- lack of adequate fire suppression facilities and arrangements
- lack of a detailed tourism development plan

Gjirokastra

The World Heritage property Museum-City of Gjirokastra was inscribed on the World Heritage List in 2005, and in 2008 the property was extended to include the city of Berat and renamed as Historic Centres of Berat and Gjirokastra. They were inscribed on the basis of criteria(iii) and (iv) as per Decisions 29 COM 8B.48 and 32 COM 8B.56.

Criterion (iii): Berat and Gjirokastra bear outstanding testimony to the diversity of urban societies in the Balkans, and to longstanding ways of life, which have today almost vanished. The town planning and housing of Gjirokastra are those of a citadel town built by notable landowners whose interests were directly linked to those of the central power. Berat bears the imprint of a more independent life-style, linked to its handicraft and merchant functions.

Criterion (iv): Together, the two towns of Gjirokastra and Berat bear outstanding testimony to various types of monument and vernacular urban housing during the Classical Ottoman period, in continuity with the various Medieval cultures which preceded it, and in a state of peaceful coexistence with a large Christian minority, particularly in Berat.

Over the last thousand years it was invaded by Ottoman Turks, Italians and Germans, and this mixture of prosperity and insecurity has led to the development of the architecture that it is still preserved today.

The town itself was built by big landowners and has a castle that has origins in the 13th century, named Citadel. This is one of the biggest castles in Balkan. With the decline of the Byzantine Empire, it became the residence of the very powerful Zenebeshi feudal clan.

The city has some typical dwellings called the Turkish kule, typical of the Balkan region. Gjirokastra contains many of them dating back to the 18th century, but even some more elaborate ones, from the 19th century.

The surrounding historical sites show the earliest evidence of the prehistoric period such as the Goranxi Gorge. Evidence of other important sites of Antigonea and Adrianopol are also testimonies of the importance of the region even during the Greek and Roman occupation.

The archaeology of Gjirokastra is relatively unknown. Due to the proximity of the Classical and Hellenistic settlement at Jermë (Antigoneia) and the Roman city of Hadrianopolis it has frequently been assumed that the medieval fortress represents the first occupation of the site. However, this has now been challenged by the results of excavations within the fortress that have led to the discovery of ceramics from four different phases of occupation before the Ottoman period: 5th-2nd centuries B.C., 5th-7th centuries A.D., 9th-10th centuries and 12th-13th centuries A.D.

The medieval fortress, which has been dated to the second half of the 13th century, encompasses an area of 2.5 hectares. The remains of five towers and three main entrances of the original fortress can still be seen, though the fortress was substantially rebuilt and extended southwest in 1811-1812 by Ali Pasha of Tepelenë. Ali Pasha was also responsible for the construction of an aqueduct feeding the fortress from a water source on Mt. Sopot, some 10 km from Gjirokastra. Complete sections of this aqueduct were still visible at the beginning of the 20th century but were destroyed in 1932. The fortress was used as a garrison in the 19th century. During the communist period, the castle also served as a prison for dissidents.

Threats to the World Heritage Property of Gjirokastra

The site has recorderd a set of natural threats affecting the property:

Natural

- seismic threat
- wildland fires
- erosion, landslides, rock falls

Human

- lack of financial support for the monuments
- lack of a management plan
- uncontrolled urban development of Gjirokastra
- abandonment of the site by the inhabitants, which will contribute to the potential fire hazard and general degradation of the building over time
- misuse of monument by the owner with the risk of damaging the authenticity and the integrity of the building

Butrint

The property of Butrint was inscribed on the World Heritage List in 1992 as an example of outstanding universal value, meeting the cultural criterion C (iii), according to the Operational Guidelines (2005), since it bears "a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared."

Butrint is located on a low hill at the end of the Ksamil peninsula, which separates the Ionian Sea from Lake Butrint (the two are connected by the Vivari Channel). To the south lies the flat expanse of the Vrina Plain, punctuated by low hills with villages. Butrint is the best-studied ancient city in Albania, as well as being a site of extraordinary beauty, and it is in many ways a microcosm of Albanian history. Butrint was an ancient Greek city that eventually became a Roman city in Epirus.

Currently it is an archaeological site in the Sarandë District in Albania. It is located on a hill overlooking the Vivari Channel and part of the Butrint National Park. Inhabited since prehistoric times, it entered into decline in Late Antiquity, before being abandoned during the Middle Ages.

In 2003, Butrint became a designated site under the RAMSAR Convention (1971) due to its lagoon, also known as the lake of Butrint, which is now recognised worldwide as a wetland of international importance.

Threats to the World Heritage Property of Butrint

Butrint, like the other sites, is exposed to varying hazards. The more significant risks related to life and cultural heritage include

Natural

- seismic threat
- wildland fires;
- floods and sea-level rise

Human

- looting
- illegal urban sprawling in to the World Heritage sites;
- widening and modernization of the road from Saranda to Butrint within the World Heritage property

The property has registered a series of monitoring/assessment missions carried out by UNESCO and its advisory bodies since 1997.

After the civil strife in the country, a report of looting of the site was issued by the Butrint Foundation. Following the first mission outcomes at its 21st session (December 1997), the World Committee decided to include Butrint in the list of the World Heritage sites in Danger.

Following the UNESCO-ICOMOS-ICCROM joint assessment mission on the site in 2005 and its recommendations in consideration of the recorded improvements achieved and upon condition to finalize the management and conservation plan of the property and to prevent any illegal development or inappropriate construction in the site, in accordance with an effective application of the legal provisions of the new law on cultural heritage, the World Heritage Committee decided to remove Butrint from the list of World Heritage in Danger.

3. RISK ANALYSIS OF NATURAL HAZARDS

Overview

The three World Heritage sites of Berat, Gjirokastra and Butrint are exposed to various natural hazards such as earthquakes, landslides, fires and flooding. The following Table 1 provides a list of those hazards.to which the three World Heritage sites are exposed, due to their geographical location or materials, structure and condition of the buildings.

However, there are several factors that further increase the vulnerability of exposed populations and Cultural Heritage at these sites. These include limited awareness, public knowledge and training for disaster preparedness, inadequate infrastructure to address these hazards, as well as the necessary resources to maintain them, unsafe/uninhabited buildings and exploitation of natural resources.

The following are general recommendations to help reduce disaster risks noted above in these World Heritage sites:

- Identify, assess and monitor disaster risks for each of the sites periodically and prioritize risk mitigation actions.
- Reduce hazards and risks and those components underlying these where practical.
- Continue to develop appropriate systems and tools for strategic planning, codes/standards and policy making related in particular to disasters including earthquakes and fire/life safety, and protection of cultural heritage.
- Improve risk communication through early warning systems (floods, adverse weather, fire, etc.).
- Establish and implement a plan for effective disaster response and recovery activities for structures, as well as people at various levels. These may include evacuation routes, signage, temporary salvage areas etc.
- Carry out regular emergency drills to practice and review standard operating procedures for emergency response by the site staff, in cooperation with local civic defence agencies.
- Provide resources for supporting emergency responders (training, equipment, enforcement, etc.) and the infrastructure necessary to carry out this work.
- Create public awareness programs for the community, especially those living in World Heritage properties, about disaster preparedness.
- Develop and implement training programs with the public to build a culture of resilience and safety.
- Develop training, licensing and enforcement programs for professionals, including designers, engineers and architects, as well as code enforcement authorities.
- Continue to strengthen management and technical capabilities of those involved with managing historic sites, including capabilities related to Disaster Risk Management.

With regards to more specific risk Reduction prioritization recommendations, additional specific recommendations are made below.

Table 1

Hazard	Berat	Gjirokastra	Butrint
Fire (structure)	✓	✓	✓
Wildland Fire	✓	✓	✓
Geohazard (earthquake)	✓	✓	✓
Geohazard (landslide)	✓	✓	
Geohazard (rock fall)	✓	✓	
Flooding	✓		✓

FIRE

Challenges

One of the hazards with a higher probability of occurrence is fire. A fire in one of the historic residential structures in Berat for instance, that gutted the house was witnessed a few months back. However with the efforts of the local fire brigade, they were fortunately able to limit the fire to this structure before it could spread. There are many challenges related to fire, including the close proximity of structures to each other particularly in Berat and Gjirokastra which could lead to fire spreading to multiple buildings, primarily those of wood/combustible construction. Other hazard include limited smoke detection within buildings, including residential buildings and no automatic notification to emergency responders for prompt response, no automatic suppression systems, very narrow streets impacting fire vehicle access, limited/no fire-fighting water infrastructure, old/poor electrical installations and poor conditions of electrical equipment that could result in ignition sources, as well as abandoned houses that are not maintained and could represent fire hazards. There are also limited fire protection measures incorporated into the religious structures and museums that should be reviewed and assessed as to their overall effectiveness and reliability. A tailored fire strategy, should be developed as appropriate to protect these. There also currently appears to be limited awareness and training of local residents with regards to fires and protecting lives as well as the historic buildings.

Risk Reduction Recommendations

- Create a Fire Prevention Awareness campaign for local residents to raise awareness regarding fire, ignition sources, early detection and alarm, the benefit of smoke detectors in all homes, the challenges of fires at these sites, and what to do in case of a fire or other emergency. This should target not only adults but there also should be educational programs in schools to educate children.
- Develop and implement Fire/Life Safety Strategies for various structures, including religious structures and museums.
- Automatically monitor alarms from buildings in addition to banks so as to initiate early warning and notification to the fire brigade to get them to the site and begin suppression activities as soon as possible.
- Revise local codes as necessary to address fire-related challenges and make these retro-active.
- Develop, implement and enforce guidelines for protecting structures from fire during renovation work.
- See also the Emergency Responder and Infrastructure Section for additional recommendations regarding fire.

WILDLAND FIRES

Challenges

Given the close wild land/urban interface for each of these sites, there is the potential for wild land fires to adversely impact the structures and the residents, including the archaeological sites in Butrint and the Berat Castle. These fires can have an immediate impact on loss of life/injury, as well as loss of structures and cultural heritage, and can adversely impact non-combustible structural components of the various buildings including the Castle and archaeological sites. These fires also destroy vegetation. This in turn can lead to other hazards including potential landslides if this vegetation is lost. The local fire brigade trains for these events, but additional resources are recommended for assisting them in undertaking their activities as noted below.

Risk Reduction Recommendations

- Develop and implement appropriate policies and regulations regarding limiting the potential for ignition of fields, grasslands and wildfires. This includes checking ignition sources, identifying burning seasons, procedures and permits for burning, interfacing with emergency responders for controlled burns, building construction materials, developing a program to work with shepherds to limit/control their burning and developing and implementing early detection, warning and notification systems, etc.

- Review international perspectives and codes on wildfires. Develop and implement a plan for wild land management and fuel control to help control vegetation and limit the impact should a fire start, in terms of the extent of the fire, as well as limiting its impact on structures.
- Conduct a very thorough review of the wild land fire situation in Butrint. This includes ignition sources (smoking, electrical equipment, lighting, etc.) and control of combustible materials including vegetation. Additionally, the proposed fire hydrant system in Butrint needs to be very carefully reviewed and revised. This should include reviewing water supplies, piping materials, installation, hydraulic calculations and location of equipment including pumping stations and water supplies in a safe and protected area, etc. In addition, the design, layout and intended use needs to also be discussed with the local emergency responders to obtain their recommendations and input on the proposed system and how they may use it during an incident.
- Provide the necessary resources, equipment and infrastructure for the emergency responders to appropriately manage these fires. This should include vehicles and other related firefighting equipment and personnel, as well as personal protective equipment to protect the emergency responders as they undertake their activities.
- Develop, implement and enforce a public awareness campaign to help limit the potential for wild land fires. (i.e. information and regulations regarding campfires, rubbish disposal and removal, including that close to the Castle, no smoking, etc.).

FLOODS

Challenges

Berat lies on the banks of the Osum River, and Butrint is at sea level and thus prone to floods. Some of the challenges, including a lack of water-collecting areas, lack of dyke systems and drainage channels and limited pumping stations, contribute to flooding.

Risk Reduction Recommendations

- Undertake further studies to identify additional reasons behind flooding.
- Review the state of existing flood-control measures and upgrade as needed.
- Develop and implement flood prevention/mitigation measures to control.flooding (e.g., improving drainage systems, channelling of water, dams, pumping stations, reducing erosion through reforestation, etc.).
- Develop an early detection and warning program, including a system to notify residents of potential flooding, as well as plans to relocate these people.
- Develop an awareness and training program for residents.

EARTHQUAKES

Challenges

Albania has a long history of earthquakes. In June 1905, a devastating earthquake hit northern Albania. Subsequently it has been rocked by several earthquakes. The World Heritage Sites of Berat and Gjirokastra are highly vulnerable to earthquakes because of their location near fault lines and rocky terrain, which can trigger landslides and rock falls due to earthquake.

The primary geohazard affecting the city of

Berat is represented by the instability of the rock escarpments overlooking the historic city center. The risk related to this criticality is high in static conditions and could be even higher if a seismic event should occur.

The most critical zones in terms of possible site amplifications in Gjirokastra include: 1) buried narrow valleys located at the mouth of mountain streams (zone 4), carrying high volumes of coarse clastic materials to the Drino River Valley; and 2) narrow ridges bonding the buried valleys, where topographic effects highlighted by micro-tremors measurements could induce site amplification. A rigid fractured layer of conglomerates generally occupies the top of the narrow ridges (e.g., where the Castle is located) and is highly susceptible to rock falls and toppling of isolated blocks.

The territory of Butrint is heterogeneous in terms of susceptibility to seismic amplification, due to extreme geological variability. The most critical zone in terms of possible site amplifications is the coastal plain. High susceptibility to geological instability, both for differential settlements and rock falls, is related to the presence of the fault scarp bounding the Acropolis.

In addition to the above, the historic buildings appear to have limited design to be earthquake resistant and as well have suffered vagaries of time and poor maintenance. They are likely too weak to bear the lateral forces of an earthquake (CNR-IGAG 2012)[3].

Risk Reduction Recommendations

- Adequate retrofitting measures should be undertaken for historic structures so that they are safer against earthquakes. These measures should try, to retain heritage values to the maximum possible extent while ensuring optimum safety levels.
- Guidelines for earthquake safety should be adopted and implemented for any new additions or alterations to historic structures.
- Masons and craftsmen should be provided with adequate training in earthquake-safe construction practices especially for historic structures.
- In Berat, it is recommended to carry out a detailed study of structural and geo-mechanical settings of the limestone cropping out along the escarpments, if this work has not already been undertaken.
- For Gjirokastra, neither direct observation of subsoil nor Vs information are generally available for the site. No geotechnical parameters are available for a proper evaluation of the dynamic behavior of soils and rocks. An additional investigative survey and the passage to a level 3 of seismic microzonation is suggested.
- The seismic microzonation of level 1 of Butrint is affected by a high level of uncertainty because of the lack of information about lithology, thickness and shear wave velocity of the lithotypes. Lithostratigraphic and geometric uncertainty could be pulled down by means of one deep borehole located close to the Vivari channel, associated with Electrical Resistivity Tomographies (ERTs) oriented perpendicular to the fault scarp. Shear wave velocity could be detected by means of MASW measurements.

LANDSLIDE/ROCK FALL

Challenges

Given their location at the base of various hills and mountains, including Berat in the vicinity of the Tomorr Mountains, and Gjirokastra within the Gjerë mountains, both are susceptible to landslides and rock falls. Several of the comments regarding the various geological conditions noted above with respect to earthquakes are applicable here as well. In addition, there is one very large rock below the fort that needs assessment in the very near future in Gjirokastra. Part of the challenges including poor drainage systems, limited vegetation in areas to help hold the earth, and unstable rocks on the hillside/mountainside. No protection of the people or buildings in close proximity against the landslides or falling rocks contribute to the potential risk.

Risk Reduction Recommendations

- Undertake studies to identify further hazards of landslides and rock falls and locations where this may occur, and exposures should they occur.
- Develop and implement appropriate prevention and mitigation measures to limit the probability of landslides and rock falls. (vegetation management, drainage, stabilize rocks, protection against falling rocks, etc.)
- Develop an awareness and training program for residents and staff responsible for maintenance and monitoring.
- Develop and implement an early warning system to alert residents at times they may be more prone to rockslides and landslides (e.g. heavy rainfalls, etc.).

Key Vulnerability factors

A few underlying factors need to be highlighted that are increasing the vulnerability of the three World Heritage properties to the above-mentioned hazards.

Abandonment of buildings

Due to various socio-economic reasons, historic buildings are being abandoned gradually. This is quite significant in Gjirokastra and is also occurring in Berat to a certain extent. Over time, there is deterioration of these properties. They are also used by the homeless who take up residence and build fires them. As they are not being maintained, the interiors are exposed to weather a condition, which creates deterioration of the structure and electrical systems. These items are adversely impacting the cultural heritage components of these structures, and also pose a fire hazard to them, as well as those structures and the people in the near vicinity given, the close proximity of the houses.

Therefore, it is important to develop and implement a program to address these challenges, including either ways to appropriately rehabilitate these structures, or assessing them to review potential fire hazards, shutting down power, etc.

Emergency Responders and Infrastructure

The emergency responders should be commended for what they do with the limited resources available and the challenges they face. This includes the limited infrastructure for fire fighting e.g., no-limited fire hydrants, intermittent water supplies, delayed notification due to limited detection/alarm systems, narrow streets and alleys and the close proximity of the buildings making it difficult to get fire vehicles close to a fire scene. Recommendations to address some of these challenges include those noted below:

- Provide automatic notification to emergency responders regarding fire and other hazards.
- Make them aware of the heritage values of the site so that they take measures to minimize impact.
- Provide appropriate infrastructure for emergency responders to undertake their work and to limit the impact of fires on the historic cities (fire hydrant system, reliable water supply/storage, etc.).
- Further support the good work of local emergency responders and provide them with more resources including equipment (vehicles, personal protective gear, etc.) and continued training to help them undertake the important work they do in protecting the cities and their people.
- Continue to engage and review with the emergency responders their particular additional needs to help protect each of these World Heritage sites and effectively respond to the varying disasters that each is exposed to.

Lack of Maintenance and Degradation of Structures

There are several areas where a lack of maintenance is adversely impacting the Cultural

Heritage at these sites either directly or indirectly. These and others should be addressed and a program put in place to ensure they will be properly taken care of in the future. The following Risk Reduction recommendations are proposed:

- Clean up rubbish, particularly surrounding the Castle in Berat. This is a fire hazard and also contributes to additional people adding their rubbish to the piles.
- Part of the Castle wall has collapsed. The cause of this should be identified and repairs made, as well as additional assessments to see if this may occur in other areas.
- Infrastructure should be properly maintained. This includes the fire hydrants and water supplies to these, electrical systems and infrastructure in the cities, etc.

4. GUIDELINES FOR RISK REDUCTION OF WORLD HERITAGE PROPERTIES

Disaster management principles need to be developed and made an integral part of the site management plans (Table 2). The impact of disasters at World Heritage properties may be very significant as it could:

- Adversely affect their "Outstanding Universal Value" which justified their inscription on the World Heritage List;
- Result in loss of lives and assets for the local people, disrupt their communities and threaten the security of visitors;
- Negatively affect the local economy and tourism.

Through this project, UNESCO Venice Office, ICCROM and the experts participating in the training were able build a shared understanding with trainees and with the representatives of the relevant governmental agencies in charge of cultural heritage in Albania upon the importance of the following:

- More coordination between a given World Heritage property management systems and the disaster management institutional framework of the nation and region in which the property is located;
- Prioritization of the risk and their solutions should be a well-governed process to be shared by all relevant stakeholders on site, without delegating pre-cooked solutions to the hands of "external technicians";
- Multidisciplinary scientific approach is needed in different fields of risk for a thorough risk assessment which should encompass multiple settings at a given site. For instance, archeologists should be able to integrate with geologists and seismic engineers to better understand the magnitude of geo hazards at stake. Moreover, site managers should also be able to understand scientific-based evidence when they have to consider Disaster Risk Management before disasters occur in order to prevent and/or mitigate them;
- Risk management plans are not stand-alone plans. They need to be integrated into the management plans of the site(s);
- Disaster Risk Management should be able to both prevent or reduce the impact of disaster on the values of World Heritage site properties, and to human lives and livelihoods;
- Disaster Risk Management should be able to secure resilience to the core value upon which the property was inscribed on the WH List. This should be the driving element to risk plans development;
- Significant considerations should be placed on the longer-term vulnerability factors (lack of maintenance, deterioration etc.) which may turn a small hazard into a larger scale disaster;
- Management planning is valuable not just for World Heritage sites but for any heritage sites. Therefore, World Heritage sites can play a catalyst role for enhancing risk resilience of other sites regardless of their designation status.

Table 2. Objectives and Priority Actions recommended.

OBJECTIVES	PRIORITY ACTIONS
1. Strengthen support within relevant global, regional, national and local institutions to reduce risks at World Heritage properties Global actors for disaster reduction should give more consideration to cultural and natural heritage among the issues to be considered when defining their strategic goals and planning their development cooperation activities. At the same time, general disaster reduction strategies at regional, country and local levels must take into account and integrate concern for world cultural and natural heritage in their policies and implementation mechanisms	*Action 1.1* Promote cultural and natural heritage, and its potential positive role for disaster reduction as part of sustainable development, within relevant international development institutions, conventions and global forums and with other potential financial partners, as a means of raising support for the protection of World Heritage from disasters
	Action 1.2 Strengthen policies and funding provisions for disaster reduction within the World Heritage system, for instance by including disaster and risk management strategies in the preparation of Tentative Lists, nominations, monitoring, periodic reporting and International Assistance processes
2. Use knowledge, innovation and education to build a culture of disaster prevention at WH properties The building of a culture of prevention, at all levels, is one of the key elements for a successful disaster reduction strategy. Experience shows that reacting *a posteriori*, especially as far as heritage is concerned, is an increasingly ineffective way of responding to the needs of people affected by disasters. Training, education and research, on relevant traditional knowledge as well, are the most effective ways of developing a culture of preparedness. This particular area of actions fits entirely within the broader mandate of UNESCO as the UN intellectual arm, in particular for establishing global knowledge networks	*Action 2.1* Develop updated teaching/learning and awareness-raising resource materials (guidelines, training kits, case studies and technical studies, glossaries) on disaster reduction for World Heritage, and disseminate them widely among site managers, local government officials and the public at large
	Action 2.2 Strengthen the capacity of World Heritage property managers and community members through field-based training programmes, to develop and implement risk management plans at their sites and contribute to regional and national disaster reduction strategies and processes
3. Identify, assess and monitor disaster risks at WH properties The first step to reducing disasters and mitigating their impact is the identification of possible risk factors, including risks from global agents such as climate change. The vulnerabilities from disasters to World Heritage properties must be therefore identified, assessed in their level of priority and closely monitored so as to inform the appropriate risk management strategies	*Action 3.1* Support risk identification and assessment activities at World Heritage properties, including consideration of climate change impact on heritage, consideration of underlying risk factors, all necessary expertise and the involvement of relevant stakeholders as appropriate
	Action 3.2 Develop a World Heritage Risk Map at the global level or at regional levels to assist states's parties and the committee to develop better responses

Key Words: Capacity Building, Disaster Risk Management (DRM) in Cultural Heritage sites, geohazard assessment, Disaster Preparedness and Mitigation, Fire, Wildland Fire.

Table 2. Continued...

OBJECTIVES	PRIORITY ACTIONS
4. Reduce underlying risk factors at WH properties When a disaster occurs, there are a number of underlying factors that can significantly aggravate its impact. These include land/water and other natural resources management, industrial and urban development, and socio-economic practices. Removing the root causes of vulnerability often implies the identification and reduction of underlying risk factors associated with human activities	*Action 4.1* Give priority within international assistance to helping states's parties in implementing emergency measures to mitigate significant risks from disasters that are likely to affect the Outstanding Universal Value, including the authenticity and/or integrity of World Heritage properties
	Action 4.2 Develop social training programmes for communities living within or around World Heritage properties, including consideration of heritage as a resource to mitigate physical and psychological damage of vulnerable populations, particularly children, during and in the aftermath of disasters
5. Strengthen disaster preparedness at World Heritage properties for effective response at all levels The worst consequences of natural or human - made disasters can often be avoided or mitigated if all those concerned are prepared to act according to well-conceived risk reduction plans, and the necessary human and financial resources, and equipment are available	*Action 5.1* Ensure that risk management components with identified priorities are integrated within management plans for World Heritage properties, as a matter of urgency. For World Heritage cultural properties, the scope of these plans should address ways of protecting the key assets that contribute towards the Outstanding Universal Value and should also include the protection of any significant original archival records that contribute to their heritage value, whether or not they are located within the boundaries of the World Heritage property. For natural properties, such plans should be oriented to protecting the key values for which the properties were inscribed as well as their integrity
	Action 5.2 Ensure that all those concerned with the implementation of disaster reduction plans at World Heritage properties, including community members and volunteers, are aware of their respective roles and are well and systematically trained in the application of their tasks

NOTES

[1] According to the World Bank (2012) ranking. Website: http://data.worldbank.org/country/albania

[2] Tragically, a few weeks following the training a fire swept through Berat and engulfed unoccupied historical residential houses and apartments in the heart of the town's historical centre. This happening, was in fact, a hypothetical case scenario developed by our trainees (see Annexes) and this unforeseen event again demonstrated the immense exposure that heritage sites are subject to everyday. Both natural and man-made events have the power to destroy or severely undermine heritage sites to the extent that their unique value is irremediably lost.

[3] Assessment Analysis of Seismologic Risk and geohazard vulnerability of first level in major Cultural Heritage Sites of Albania.

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ANNEX I

POWER POINT PRESENTATIONS PRODUCED AT THE TRAINING ON NATURAL DISASTER RISK MANAGEMENT IN WORLD HERITAGE SITES OF ALBANIA

POWER POINT PRESENTATIONS PRODUCED AT THE TRAINING ON NATURAL DISASTER RISK MANAGEMENT IN WORLD HERITAGE SITES OF ALBANIA

The Disaster Risk Reduction (DRR) training was conducted in a timely manner as it coincided with the development of the Disaster Risk Management (DRM) plans for three World Heritage Site in Albania, in Berat, Butrint and Gjrokastra. The benefits of the seeds sown throughout the short and intensive training and coaching activities produced a lasting legacy that saw DRR principles and concepts integrated into the DRM plan for Berat.

Project in Butrint and Gjirokastra have now the capacity to also follow this good practice.

Tragically, a few weeks following the training a fire swept through Berat and engulfed unoccupied historical residential houses and apartments in the heart of the town's historical centre. This happening, was in fact, a hypothetical case scenario developed by our trainees (see annexes) and this unforeseen event again demonstrated the immense exposure that heritage sites are subject to everyday. Both natural and man-made events have the power to destroy or severely undermine heritage sites to the extent that their unique value is irremediably lost.

As a general rule there is a vast distinction between 'rules on paper' and 'rules in practice'. The real threshold between the success and failure of a system of governance (regimes) lies in their level of effectiveness. This depends on whether the regime is translated by the social constituents (main stakeholders) into everyday practices or whether the plan is merely fed into 'dead letter documents' and not utilized. The importance and effectiveness of management plans are dependent on their capacity to embody guiding DRR principles within the overall management system(s) in force. This step is fundamental to ensure the resilience of heritage sites against disasters and unforeseen events and also against potential risks to the site's authenticity, integrity and their outstanding universal value.

Taken as a whole, a DRR management plan should be considered as a continuous cycle of an ongoing process of revision and change with inputs from monitoring and evaluation mechanisms followed by subsequent implementations of further action. This process is rather unique to the DRM cycle, which is characterized by constitutive and interconnected phases of identification and assessment of risk, prevention and mitigation, emergency preparedness and response, and recovery actions, whenever required.

Whilst the DRR cycle in its entirety was introduced and analyzed throughout the DRR training held in Berat, the scope and purpose of the current chapter is to report on the concrete outcomes of the workshop in for of presentations elaborated by three working groups and presented at the Conference of Berat.

The intention of such a project was to provide site managers and heritage administrators throughout countries in South East Europe with an effective methodological framework to make World Heritage Sites more resilient to risk at the global level.

Case studies

Presented at the International Conference on
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GJIROKASTRA

AUTHORS:

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Brief history of Berat

Berat and Gjirokastra are inscribed as rare examples of an architectural character typical of the Ottoman period. Located in center Albania, Berat bears witness to the coexistence of various religious and cultural communities down the centuries. It features a castle, locally known as the Kala, most of which was built in the 13th century, although its origins date back to the 4th century BC. The citadel area numbers many Byzantine churches, mainly from the 13th century, as well as several mosques built under Ottoman era which began in 1417.

Risk Analysis

Attributes and Values

1. **Architecture: a) Byzantine Churches** (architectural, artistic, Christians and spiritual traditions preserved, historic, education value). **b) Mosques built under the Ottoman era** (architecture, spiritual traditions, historic). **C) Fortifications** (archaeological, architectural, historic). **D) Vernacular buildings** (ottoman architecture, social, functional values, continuously inhabited, economic).
2. **Coexistence** (combination of various religious and cultural traditions)
3. **Artisan tradition** (artistic, craft values)
4. **Urban heritage** (diversity of urban societies, landscape, lifestyle)
5. **Landscape** (environment values, geological value)

Stakeholders involved in the DRM Plan

- Municipality of Berat
- Regional Directorate of National Culture
- Institute of Culture Monuments
- CEZ
- Ministry of Tourism, Culture, Youth and Sports
- Police of Fire Protection and Rescue
- Ministry of Interior Affairs
- Directorate of Museums
- Directorate of Water Supply
- Prefecture of Berat (Emergency Unit)
- Regional District of Berat
- Drainage Board
- Directorate of Forests
- Red Cross
- Citizen Forum
- Chamber of Commerce
- Directorate of Public Health
- Military Division of Berat
- Police Station
- ASHA
- Agency of Environment
- UNESCO office

ANALYSIS

Hazards and Vulnerabilities

IMMEDIATE HAZARDS:

1. FIRE
2. ROCK FALL
3. LANDSLIDE
4. FLOODS
5. EARTHQUAKE

OTHER HAZARDS:

1. PROGRESSIVE DETERIORATION
2. ABANDONMENT
3. IMPROPER RESTAURATIONS
4. LITTLE CONTROL ON THE BUFFER ZONE

FIRE

(VULNERABILITIES)

Vulnerabilities to cope immediately

- Lack or improper functioning of the existing hydrants.
- On air electric lines and worn out electric installations inside the houses.
- Narrow streets and alleys that make it difficult for fire suppression vehicles to pass through.
- Lack of 24 hours water supply.
- Lack of electric and fire projects for the houses.
- Lack of fire suppression equipment installed in the neighborhood.
- Abandonment and lack of maintenance.
- Lack of awareness.

Other Vulnerabilities

- Lack of smoke detectors, manual and automatic fire suppression equipment inside the houses
- Materials; wood constructions, carpets, (Combustible material)
- Vegetation growth
- Scattered garbage
- Nearness of Trees
- Nearness of houses
- Lack of water collecting areas

- Lack of evacuation exits
- Alarms not connected to the fire department
- Lack of awareness
- Lack of fire management plans during restoration
- Lack of signage
- Lack of drills
- Lack of citizen training
- Water cisterns inside traditional houses not in use
- Abandoned houses
- Lack of Space for immediate interventions
- Lack of Storage for works of art etc
- Improper measures for visitors
- Poor security

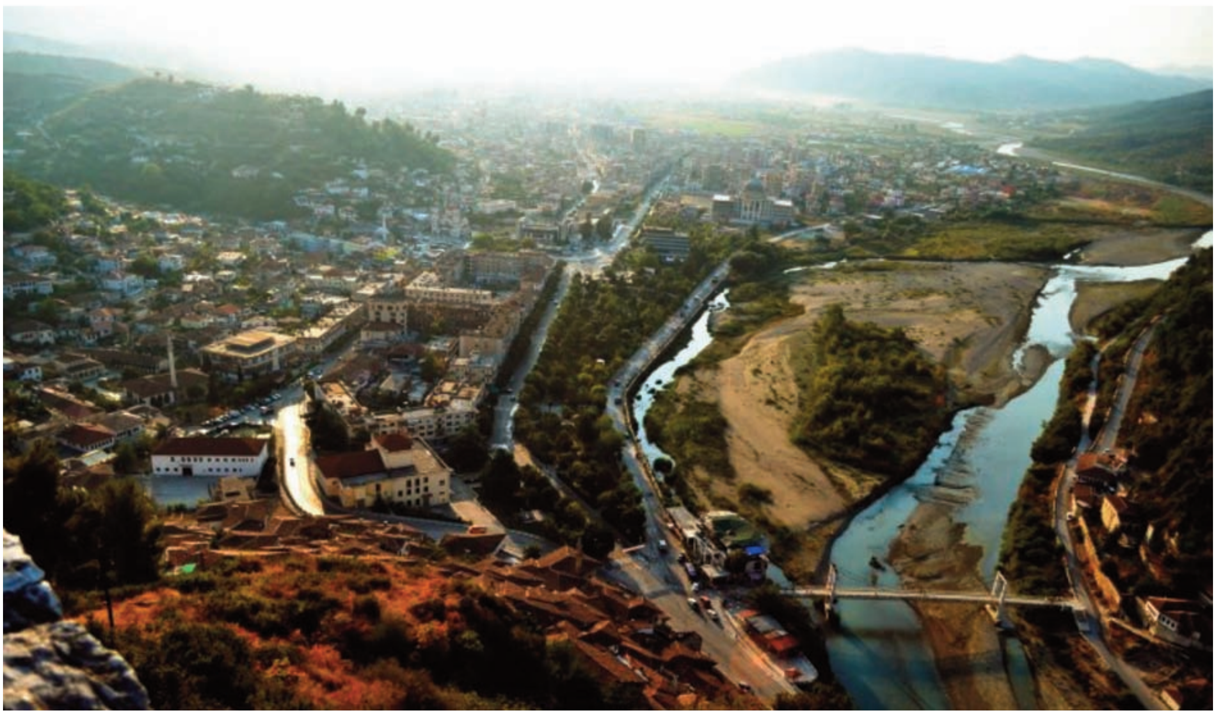
ROCK FALL

- Poor drainage system
- Unstable hilly rocks
- Unconsolidated hilly slopes
- No protection against the falling rocks
- Soft composition of rocks
- Not a thorough seismic and geological research
- Lack of funds
- Civilian houses are near
- The site overlooks the main road
- Scarceness of trees spread on the hill

LANDSLIDE

- Lack of Drainage system
- Poor wall construction
- Unstable hilly rocks
- Unconsolidated hilly slopes
- Nearness of Houses, people living near or on the slopes.
- Scarceness of trees spread on the hill
- Lack of sewage system for the houses built recently

FLOODS/RAINFALL



FLOODS

- Level of discharging pipes is not high enough in the river
- Lack of a collector
- Poor Drainage system
- Poor condition of the houses
- Lack of river embankments
- Lack of dams
- Lack of maintenance for the river bed
- Lack of maintenance for heritage assets such as buildings
- Lack of training
- Exposed electric cables
- Nearness of Houses
- Difficult terrain

EARTHQUAKE

- Lack of a Seismic Microzonation
- Unconsolidated buildings and fortification walls
- Materials (for example different phases of restorations)
- Lack of Storage for works of art etc
- Nearness of houses
- Electrical and telephonic lines are exposed
- Unstable hilly rocks
- Lack of Space for immediate interventions
- Abandoned houses
- Location related to mountain (geographic positioning)
- Lack of signage for evacuation
- Lack of river embankments
- Illegal buildings and interventions
- Nearness of trees to the walls

SCENARIO

Gorica Quarter; a monument house of category II near the church of Saint Church of Saint Spiridon which is Category I This house is divided between two owners, one belongs to Scott Logan and One belongs to Vali Prifti. Vali Prifti doesn't live in the building for years, while Scott Logan does live.

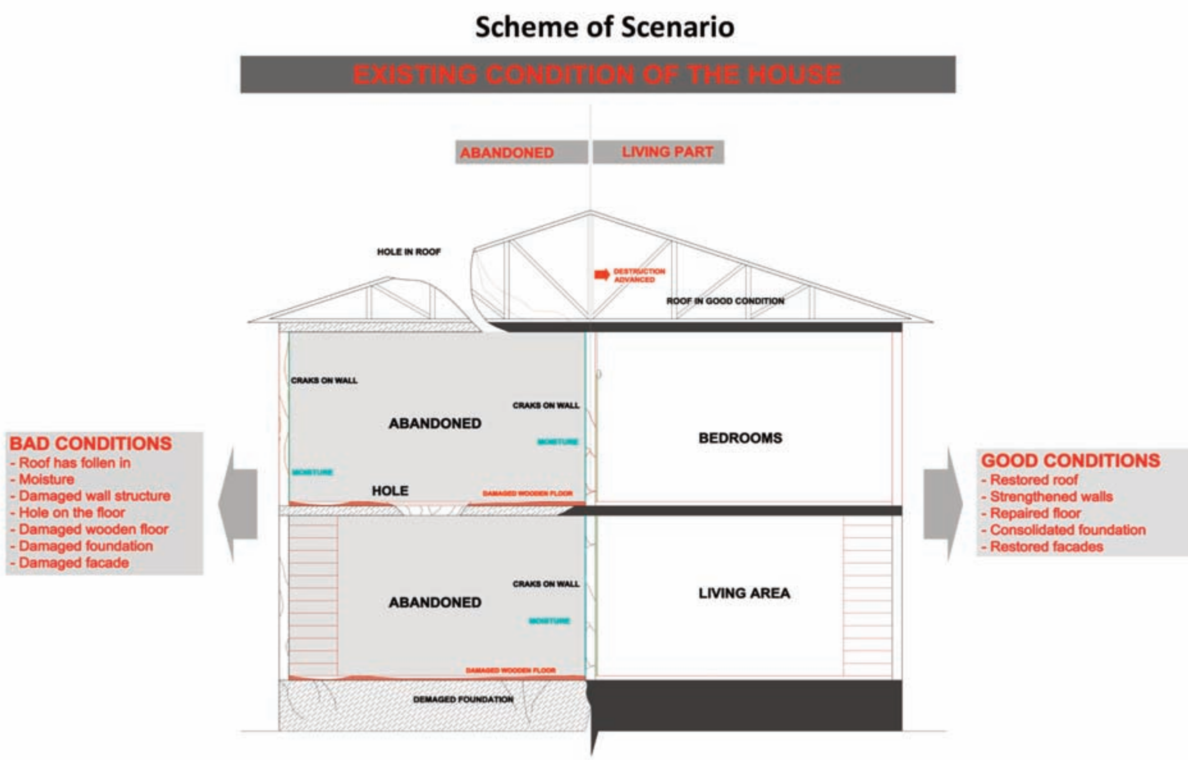
Vali Prifti's part has undergone these damages because of abandonment :

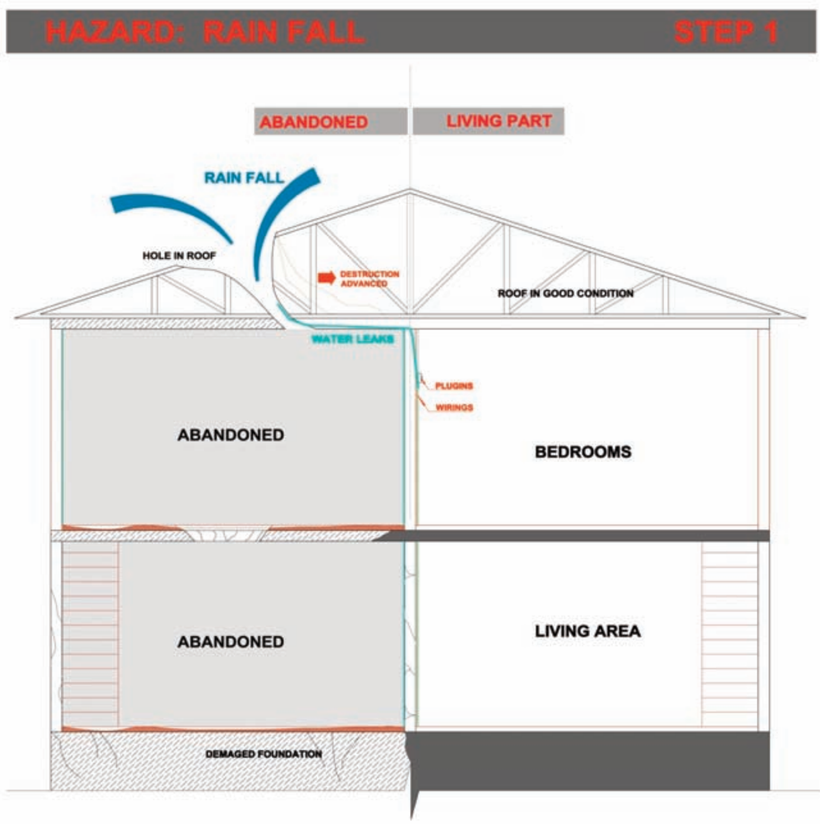
- Roof has fallen in
- Moisture
- Damaged wall structure (Cracks)
- Weakened foundations
- Floor has given in.
- These have damaged the other part of the house:
- Damaged roof
- Moisture
- Damaged walls
- Foundations weakened.

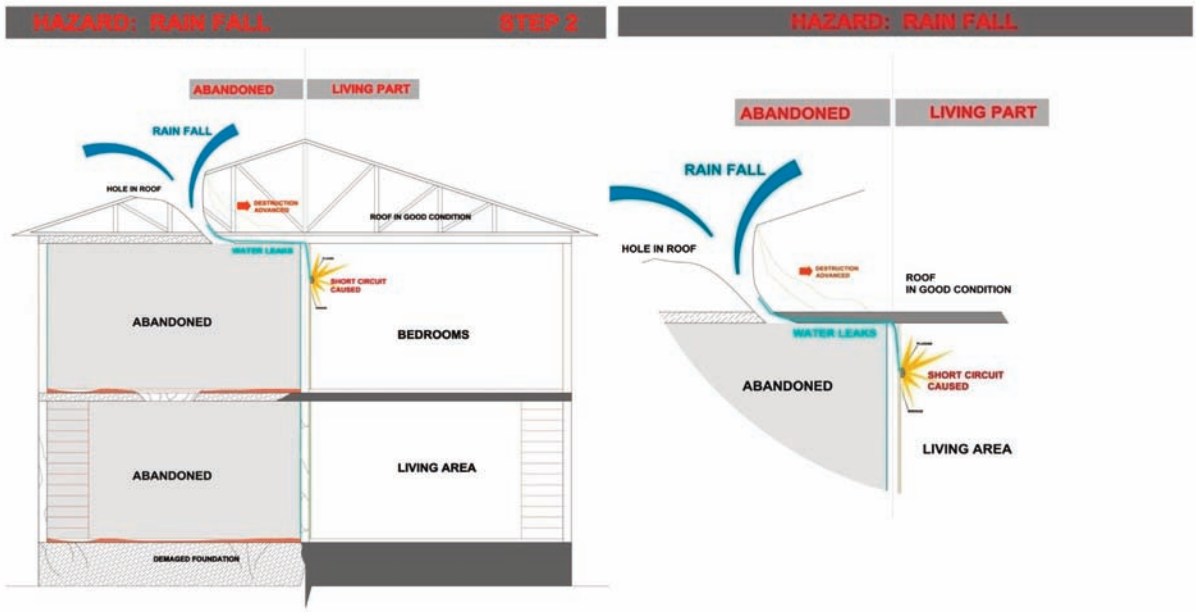
This situation makes the house vulnerable to hazards. The house is vulnerable to fires, earthquake and heavy rain. There is a whole in the roof of the abandoned house through which water flows in freely. There is heavy rain and large amount of water gets through the wall. The water penetrates in the other house and reaches the electric spine causing immediate fire. There are no fire detection and fire suppression equipment. The inhabitants notice the fire late because the disaster is taking place in the bedrooms. The fire spreads rapidly through the wooden structures of the second floor and spreads in the source house as well as in the surrounding area which has high vegetation. The house is a hostel and tourists might be endangered with a high economic impact. The houses have little compartimentation and the fire has little chance of being suppressed. There is a high possibility that the fire might reach the power pole and the other houses which are very close.
Firefighter Department is notified late and there is already some damage done when they arrive. The terrain makes it difficult for fire officials to arrive with a vehicle at the place. Because the houses are very close to one another the fire fighters have difficulty in limiting the fire within the already damaged area. There are no hydrants near.

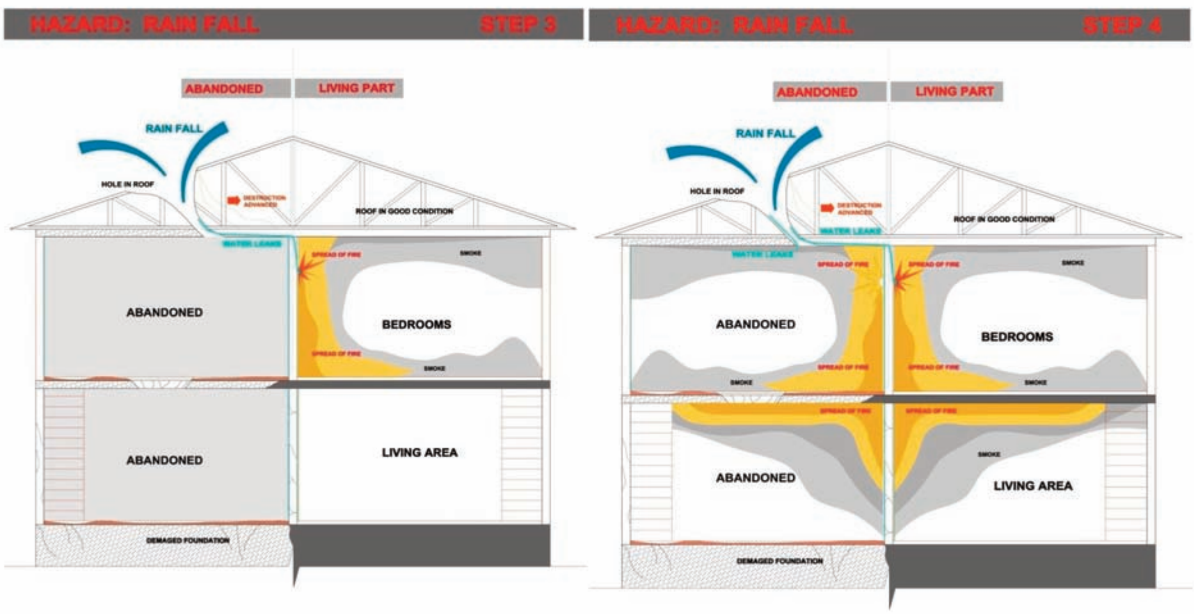
Location:

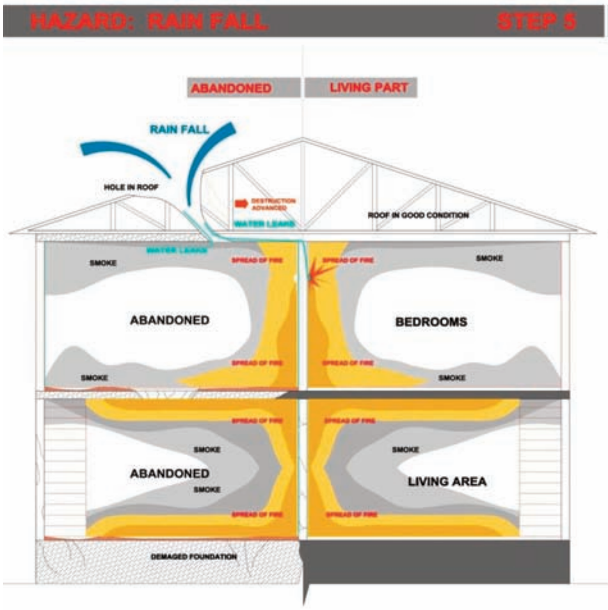
Gorica Quarter. A monument house of Category II.

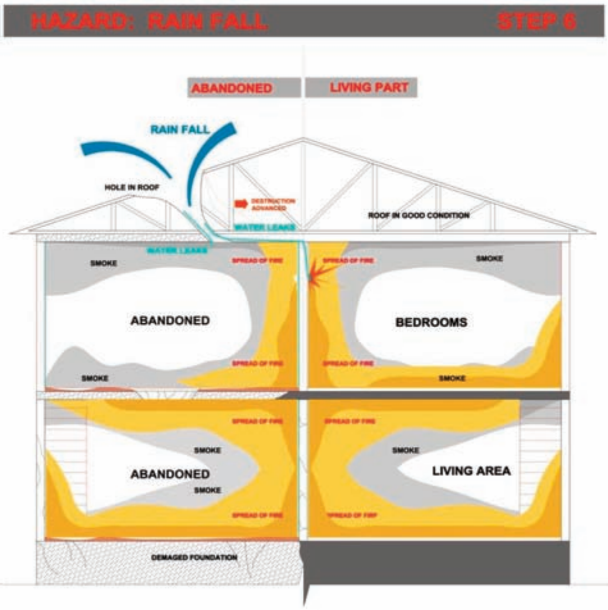

Scheme of Scenario
EXISTING CONDITION OF THE HOUSE
ABANDONED
LIVING PART
HOLE IN ROOF
DESTRUCTION ADVANCED
ROOF IN GOOD CONDITION
CRAKS ON WALL
ABANDONED
CRAKS ON WALL
MOISTURE
MOISTURE
HOLE
DAMAGED WOODEN FLOOR
BEDROOMS
BAD CONDITIONS
- Roof has follen in
- Moisture
- Damaged wall structure
- Hole on the floor
- Damaged wooden floor
- Damaged foundation
- Damaged facade
GOOD CONDITIONS
- Restored roof
- Strengthened walls
- Repaired floor
- Consolidated foundation
- Restored facades
CRAKS ON WALL
ABANDONED
MOISTURE
LIVING AREA
DAMAGED WOODEN FLOOR
DEMAGED FOUNDATION

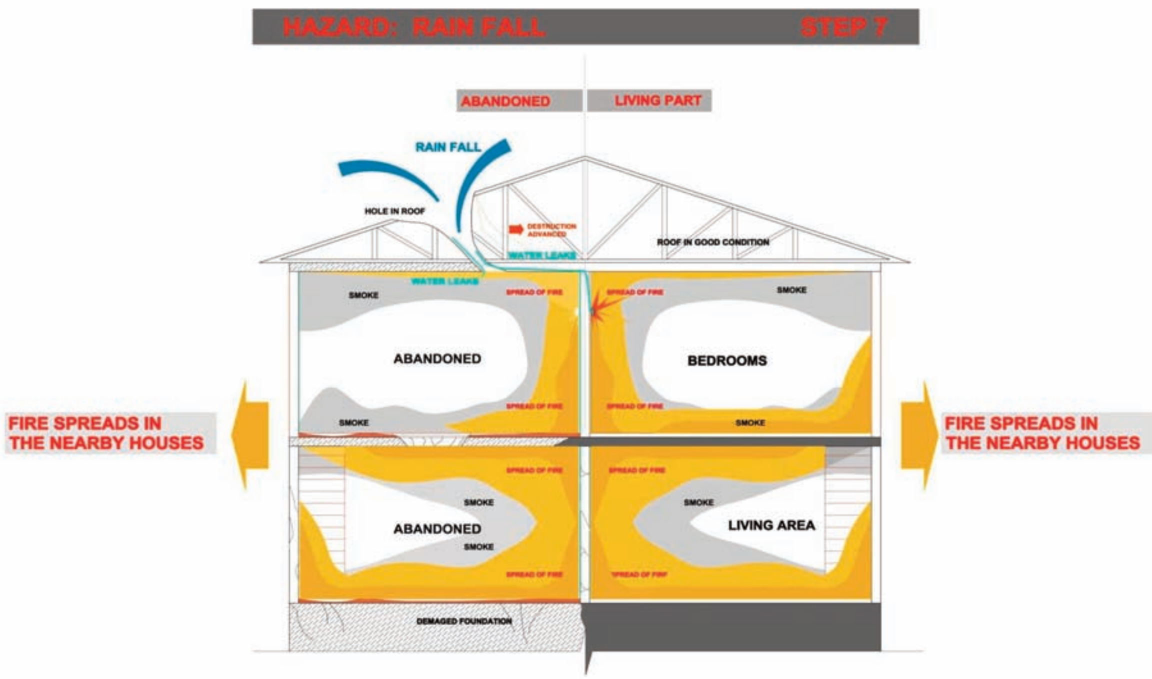

HAZARD: RAIN FALL
STEP 1
ABANDONED
LIVING PART
RAIN FALL
HOLE IN ROOF
DESTRUCTION ADVANCED
ROOF IN GOOD CONDITION
WATER LEAKS
PLUGINS
WIRINGS
ABANDONED
BEDROOMS
ABANDONED
LIVING AREA
DEMAGED FOUNDATION


HAZARD: RAIN FALL
STEP 2
HAZARD: RAIN FALL
ABANDONED
LIVING PART
RAIN FALL
HOLE IN ROOF
ROOF IN GOOD CONDITION
WATER LEAKS
SHORT CIRCUIT CAUSED
ABANDONED
BEDROOMS
LIVING AREA


HAZARD: RAIN FALL
STEP 3
HAZARD: RAIN FALL
STEP 4
ABANDONED
LIVING PART
RAIN FALL
BEDROOMS
LIVING AREA


HAZARD: RAIN FALL
STEP 5
ABANDONED
LIVING PART
RAIN FALL
HOLE IN ROOF
ROOF IN GOOD CONDITION
SMOKE
ABANDONED
BEDROOMS
SMOKE
ABANDONED
LIVING AREA
DEMAGED FOUNDATION


HAZARD: RAIN FALL
STEP 6
ABANDONED
LIVING PART
RAIN FALL
HOLE IN ROOF
ROOF IN GOOD CONDITION
SMOKE
ABANDONED
BEDROOMS
SMOKE
ABANDONED
LIVING AREA
DEMAGED FOUNDATION


HAZARD: RAIN FALL
STEP 7
ABANDONED
LIVING PART
RAIN FALL
HOLE IN ROOF
ROOF IN GOOD CONDITION
SMOKE
ABANDONED
BEDROOMS
FIRE SPREADS IN THE NEARBY HOUSES
FIRE SPREADS IN THE NEARBY HOUSES
SMOKE
ABANDONED
LIVING AREA
DEMAGED FOUNDATION

SPREAD OF FIRE

DECEMBER, 2011

PREVENTION AND MITIGATION

Mitigation and preparedness measures can help reducing disaster risk form hazards and vulnerability on the site

1. **Documentations and inventory** of each monument in the site in details will help in preparing the evacuation plan. Documentation should include:
   - the building structure of the building (the problems, where is damaged, how is build etc.)
   - The object with value and where are located
   - Prioritization of the significance of the monument
2. Improvement of the **Electrical system** in the site
3. **System of Hydrants**
4. **Alarm system** (installing equipment and proper signature, suitable vehicles of transportation in the historic center etc.)
5. **Strong and clear legislation** that protects from any improper intervention
6. **Maintenance of the green areas.** Vegetation
7. **The regular collection of the garbage**
8. **Evacuation plan**

EMERGENCY PREPAREDNES AND RESPONSE

Emergency Equipment

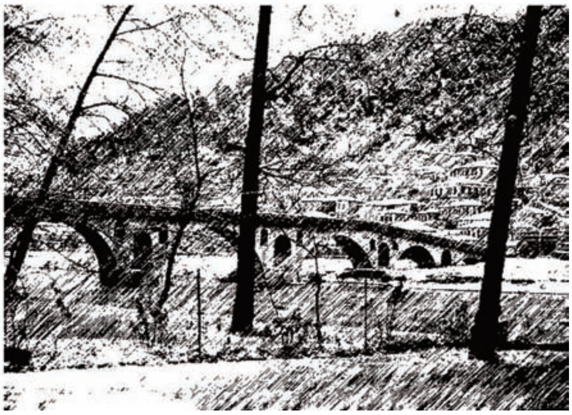
- Extinguishers will be placed near the areas that are dense with houses and that are easily accessed by people in case of emergency
- Smoke alarms will be placed inside the houses
- CCTV-s will be placed on the roof of the church and on Tabya tower (risk of theft)
- Water from the pipes will be in the form of rain and will not have high pressure so as to damage the least the heritage structures
- The hoses will be connected to hydrants positioned on the lower and upper roads

Evacuation Plan

- The house has two doors, and a garden that can be easily crossed. People will exit from the door on the back of the house and will be collected in the school on the southeast of the quarter
- The shortest way for pedestrians and transport of heritage assets is to the back of the house.
- The emergency vehicles will take the road on the west
- Team members will protect the three doors from theft and one guard will stay on the garden
- The firefighters will provide many barrels to transport the injured

PROPOSE AND EMERGENCY TEAM

- Coordinator - Manager of Cultural Heritage in the Regional Directorate of National Culture
- Detection – Police of Fire Protection and Municipality of Berat
- Safety and Security – Police of Fire Protection and Rescue
- Administration and Finance – Berat Prefecture
- Spokesperson for the Media – Police Station
- Cultural Heritage – Institute of Cultural Heritage
- Natural Heritage – Agency of Environment



RECOVERY AND REHABILITATION
Short Terms

- Damage Assessment: Buildings assessment, landscape assessment,
- Inspect the structural stability, material damage, loss of authenticity or integrity, environmental setting
- The tools include pictures, drawings, technical reports
- Institute of Cultural Monuments, Directorate of Monuments, Municipality of Berat will inspect the affected area
- Recovery activities in short term:
  - The area will be isolated
    - Transport will be prohibited
    - Electricity supply will be disconnected
    - The houses that are burned will be temporarily covered for not being further damaged by climate conditions
    - The walls in danger of falling will be temporarily supported with appropriate structures
    - People and heritage assets will be rescued to the school of the neighborhood

RECOVERY AND REHABILITATION

Long Terms

1. Restoration and reconstruction of the property in accordance with the integrity and authenticit
2. Rehabilitation of the environment
3. Review of cultural heritage legislation
4. Review of Disaster Management
5. Assessment of human and economic resources
6. Stakeholder involvement and community participation
7. Educational and Awareness raising activities
8. Introduction of a monitoring system

DISASTER RISK PREPAREDNESS AND MANAGEMENT PLAN OF BUTRINT

Berat, May 2012

Prepared by:

Gezim HALILI - MTKRS
Liri SHEHAJ - IMK
Evjeni THOMAGJINI - PKB
Elionilda RRAKU – DRKKS
Eralda Bushi- IMK

BRIEF DESCRIPTION

Butrint, ancient Buthrotum, a port from Hellenistic to Ottoman times, is a UNESCO World Heritage Site in south-west Albania. Situated on the Straits of Corfu, and surrounded by a picturesque lagoon, it is one of the most remarkable archaeological sites in the Adriatic Sea Region

Butrint has been inscribed on the World Heritage List on April 1992, on the basis of the Criterion iii:

The evolution of the old town of Butrinti's natural environment, which led its inhabitants to leave the site at the end of the Middle Ages, means that this archaeological site provides valuable evidence of ancient and medieval civilizations on the territory of modern Albania.

Inhabited since prehistoric times, Butrint has been the site of a Greek colony, a Roman city and a bishopric. Following a period of prosperity under Byzantine administration, then a brief occupation by the Venetians, the city was abandoned in the late Middle Ages after marshes formed in the area. The present archaeological site is a repository of ruins representing each period in the city's development

ATTRIBUTES	VALUES
The whole site of Butrint includes a large number of monuments, the good state of preservation of each of them, representing since 3000 years ago till medieval age of occupation history for both the settlement of Butrint and the settlements within its sphere of influence	Historical and Archaeological
The three Fortification Walls of Butrint, beginning from the earlier fortification build with big blocks of stone. The theatre. The Baptistery. The Lion Gate. Ali Pasha,s Castle	Architectonic
The combination of a changing landscape formation (i.e. patterns of erosion and silting, resulting in a shifting coastline) and the resultant changes in settlement pattern (fossilized in the archaeological record) offers a unique "landscape museum" of the effects of nature on man and *vice versa*	Geological
Areas like Vrina Plain, of potential archaeological excavations which can be done from the new generations of archaeologists	Educational
The continuity of different civilization beginning from the Hellenistic, Roman, Byzantine, Venetian, Ottoman Empire	Social

ATTRIBUTES	VALUES
The large number of the visitors is a good financial resource	Economic
The presence of different wells where religious people do some kind of rituals. (like throwing coins into them)	Spiritual and Religious
Butrint is also a Natural Park, known for a large number o trees (there are more than 24 different types of Laurel Trees), birds, fishes, turtles etc.	Natural
Different Cultural Annual Events, like the International Festival of Theatres, Miss Globe, etc.	Cultural
A strong spirit of place and a landscape of outstanding natural beauty created by the unique combination of archaeology and nature, not found on other Mediterranean sites	Aesthetical

The STAKEHOLDERS who we would involve for our DRM Plan are:

- Office of Administration and Coordination of Butrint
- Ministry of Tourism, Culture, Youth and Sports
- Ministry of Environment
- Institution of Cultural Monuments
- Institution of Archaeology
- The Local Administration (Ksamil, Xarre, Mursi and Vrine Municipalities)
- Rescue and Fire Protection Police
- Butrint Foundation
- Environmental Associations

HAZARDS	VULNERABILITIES
Fire (shepherds, cigarettes, human error, electricity, lightning)	1. Management of vegetation 2. The absence of fire fighting equipments 3. Lack of awareness of the community 4. Lack of the collaboration between the stakeholders 5. Lack of the awareness of the visitors and uncontrolled attitude 6. Management of garbages (combustible material)
Earthquake	7. Poor structures
Flooding	The low level of the site (compared with the sea level)
Rainfall	The low level of the site (compared with the sea level)

Hazards	Vulnerabilities
Long term bradisismic displacement	Being in such a bradisismic area like site is (lion gate)
Landslide	The closeness of the steep terrain with the lagoon
Vegetation (near and on the monuments, roots, bushes)	The growth of the vegetation (roots) within the wall structures causes the weakness of it and under the mosaic surfaces causes the detachment of the tesseras
Visitors	Large number of the visitors on the same time (especially pupils) (they use to walk on the top of the walls)
Garbage	The place where the garbage are collected is near the surrounding walls

PREVENTION AND MITIGATION

Mitigation and Preparedness measures

A. Fire risk inside park area.

Fire it is caused: by negligence of people (visitors) that throw cigarettes or from a human mistake, caused by the shepherds, or from the possibility of lightning in the area of the Park mitigation and preparedness measures:

- Installation of hydrants (large deposits in some parts of the park) to enable firefighting. (a project for hydrants is already prepared and need to be approved from the authorities
- Periodic control of fire extinguishing system such as pumps and other equipment for firefighting
- Put more signals "no smoking" and restrictive panels
- Management of dry vegetation and removal of dry vegetation (such as dry branches, roots etc.) from the territory of the park and not burning them inside the Park

- Open crossing paths and creating some areas cleared from vegetation to manage firefighting
- Adding more equipment that provides firefighting and installation of emergency response mechanism (including fire extinguishers) that can be used by residents or staff
- Use of refractory materials

- Training of the staff and creating a team for emergency management

Fire risk in the museum area. Mitigation and preparedness.

- Installation of a sophisticated lightning conductor (rods)
- Emergency Exit
- Installation of well distinguished Emergency Exit signs
- Installation of a proper fire and smoke detector system
- Installation of CCTV system which can be monitored in full time by a person
- Installation of a fire extinguishing system (sprinkles and manual inside the museum and hydrants in the opened area of the site)
- Improvement of the electric system (cables and wires)
- The periodic control of the Fire and Smoke Detector system, and the the fire extinguisher also
- Installation of the fire acoustic alarm
- Safe management of the combustibles

B. Mitigation and Preparedness measures in case of an Earthquake.

Consequences of earthquakes may be favored by some vulnerabilities such as cracks on wall structures, poor structures of some monuments. Earthquakes may caused damages on the landscape elements such as trees, fences; destruction of fauna and flora, loss of habitat for different species, resulting in erosion of biodiversity, can cause damages on monuments (especially on those with poor structure) damages to infrastructure transport, and sometimes can prevent emergency response

Measures:

- Consolidation of poor structure monuments
- Management of vegetation, big trees
- Creating secondary doorways and entrances (exits) to avoid isolation

Priority Actions

Fire is the main risk so it needs some priority on the disaster risk management.

- It is necessary to prepare a team (including staff, rangers, residents people) that will manage the fire risk and also to coordinated an action plan on the park area
- Providing installation of different equipments for extinguishing the fire so he can be managed before the fire fighter reach to the park. Fire department is located at a distance 20 km from the park
- The advantage is that the park will have a management plan for some risks, a prepared team to manage the risk and functional equipments to operate on time

Integration of these measures with the park management system requests:

- Developing concrete plans
- Creating an emergency team, and application of a periodic action plans on the park area.

SCENARIO

The case of a lightning at the archeological museum which is located at the acropolis (top of the hill). These might cause a short circuit that can lead to a fire ignition. The absence of the fire and smoke detector or at least a CCTV system might allow the increasing of the fire out of control until the moment that the guardian can see the smoke coming out and call the firefighters. The communes in districts do not have the firefighters service so they have to ask the help of main firefighting department in district center (that is about 22 km away from Butrint)

EMERGENCY PREPAREDNESS and RESPONSE

Our scenario is developed in a case that the fire happens out of official time working.We think that this would be the worst case of fire. According to this scenario we do not need any evacuation plan, but if the fire happens during the official time working our suggestion is:

1. First of all an Emergency Exit is required. Actually this exist but is out of function, so it needs to be repaired. From this exit people can go directly to the refuge area
2. Installation of well distinguished Emergency Exit signs

EMERGENCY TEAM

- Maintenance staff (1 person)
- Guard staff of the museum (1 person)
- Guardians on the site (3 persons)
- Site workers (2 persons)

COMANDS

- The museum guardian calls the Fire Fighter, the Site guardians and the Site Workers while the maintenance person is helping with the people evacuation. Then the guardians and the site workers can join and help with the people and heritage objects evacuation. All this process (fire alarm, calling the fire fighters and the gathering of the staff) takes less than 10 minutes.

RECOVERY AND REHABILITATION

Short Term

- Immediate damage assessment. Splitting the damaged objects from those which are not damaged
- Evaluation of damage level for each object and for the museum structure itself (done from the archaeological and engineering experts)
- Storage of the evacuated fund into safe area (safe area means optimal conditions of temperature, humidity and light)

Long Term

- Reconstruction of the museum
- Restoration of the damaged objects
- Installation of the Lightning Conductor (rods)
- Installation of the Electric System
- Installation of the CCTV system
- Installation of fire and smoke detector
- Installation of fire extinguisher
- Installation acoustic alarm

HUMAN RESOURCES

- The number of the working staff is enough also in case of emergency, considering that the number of visitors who can be inside of the museum at the same time is at maximum 30 persons. But is needed the training of the staff about how to act in case of emergency.

  For the recovery period the additional staff needed is:

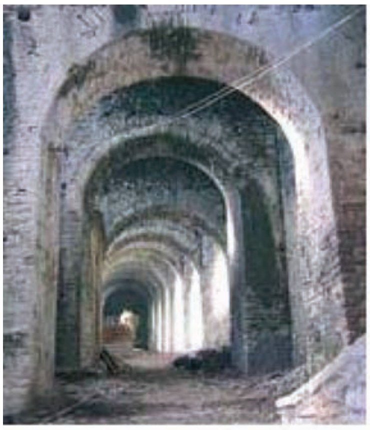
- Archaeological and engineering experts for the damage evaluation
- Archaeological Conservators and Restaurateurs

FINANCIAL RESOURCES

- Ministry of Tourism, Culture, Youth and Sports
- Butrinti Foundation
- UNESCO
- Other Foundations and Donations


TRAINING WORKSHOP ON
DISASTER RISK PREPAREDNESS
AND MANAGEMENT
PREPARED BY:
LEFTER QIRICI (PMNZSH)
ILIR LLURI (ARCHAEOLOGICAL PARK OF ANTIGONEA)
DRITAN LOLOCI (MUNICIPALITY OF GJIROKASTRA)
PABLO BALLO (CIVIL EMERGENCY)
MARSELA PLYKU DEMAJ (IMK)
CASE OF GJIROKASTRA
BERAT 2011


WORLD HERITAGE SITE SINCE 2005 – EXTENSION IN 2008



ATTRIBUTES

-Around the 13th century citadel it has a vernacular houses with turrets (Turkish Kule) characteristic of the Balkans region (17th century – 19th century
-Architectural character typical of the Ottoman Period
-Retains a Bazaar, 18th century mosque and two churches of the same period
-Its urban centre reflects a vernacular housing typical of the Balkans,
-It is a citadel town built by notable landowners whose interests were directly linked to those of the central power

VALUES

-The historic centre is remarkably well-preserved
-It has been continuously inhabited from ancient times to nowadays
-Bears witness to the wealth and diversity of the urban and architectural heritage of this region
-The vernacular architecture has some remarkable examples of houses
-Bears outstanding testimony to the diversity of urban societies in the Balkans and to longstanding ways of life which have today almost vanished
-Bear outstanding testimony of various types of monuments and vernacular urban housing

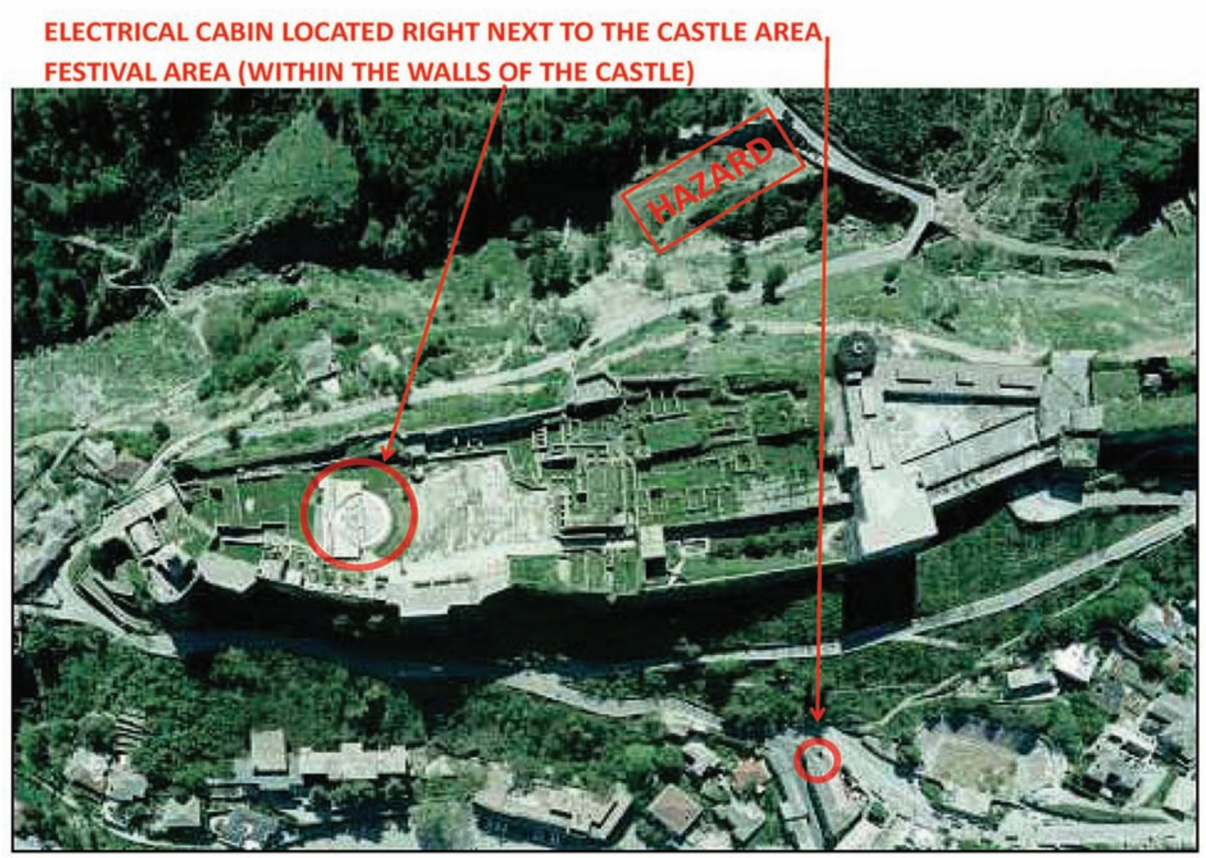
Stakeholders to be involved in making DRM Plan

- Ministry of Tourism, Culture, Youth and Sports
- Municipality of Gjirokastra
- Institute of Cultural Monuments
- Regional Directorate of National Culture - Gjirokastra
- Police for Fire Protection and Rescue
- Office of Coordination of Historical Centre (WH) UNESCO
- Directorate of Water Supply and Sewage
- Institute of Archaeology
- CEZ (Power Supply)
- Other

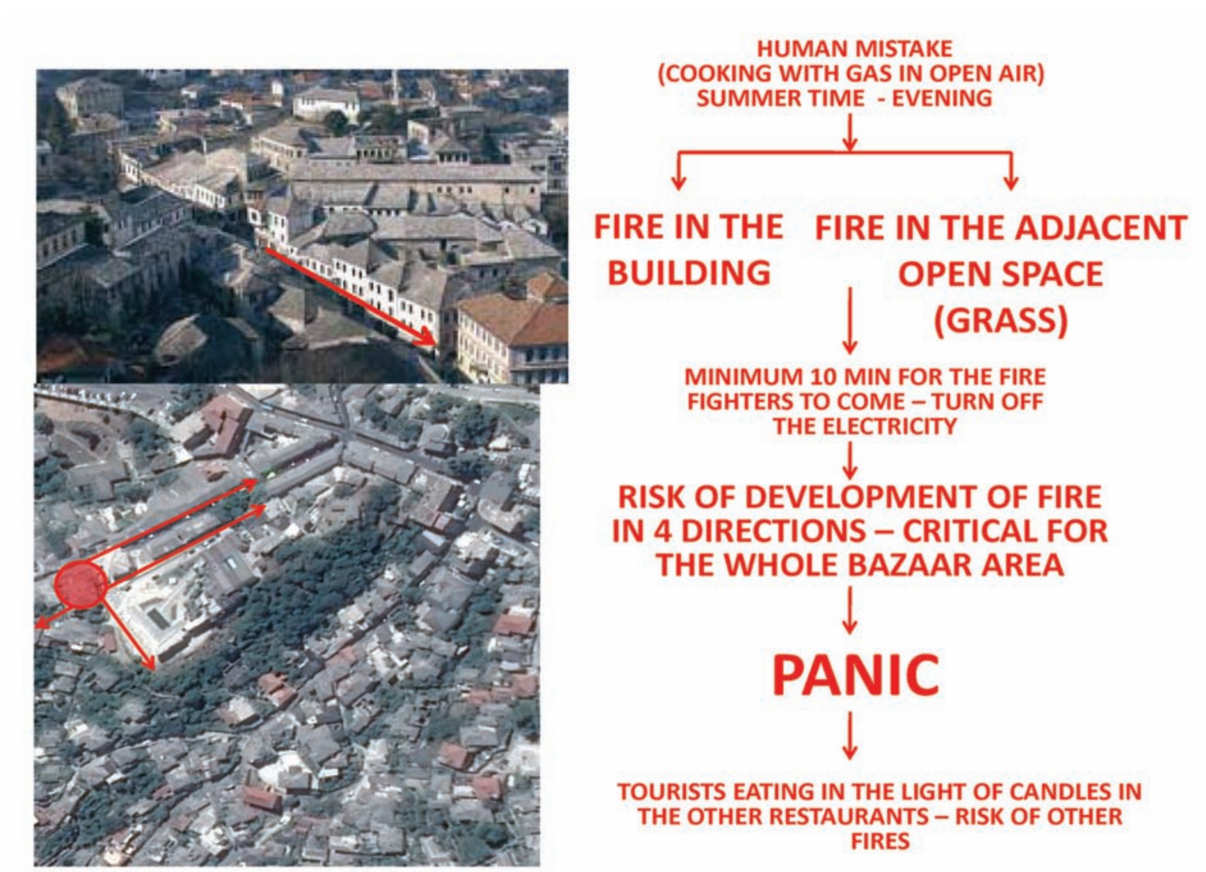
TYPES OF HAZARDS AND VULNERABILITIES

LANDSLIDE
(IN THE STEEP SLOPE OF THE CASTLE HILL)


SNOW FALL LOAD ON THE ROOFS
HAZARD
FIRE
(BURNING OF GARBAGE, LIMITED ELECTRICITY, HUMAN MISTAKES, SHEPHERDS FIRE, GAS HEATER, CANDLES, ELECTRICITY SYSTEM)
VULNERABILITY
COVERAGE OF THE ROOFS WITH SLATES
NO COLLECTION OF GARBAGE


ELECTRICAL CABIN LOCATED RIGHT NEXT TO THE CASTLE AREA
FESTIVAL AREA (WITHIN THE WALLS OF THE CASTLE)
HAZARD


RAIN FALL - STREAMS CREATED IN THE STONE STREETS
HAZARD
DESTROYED HOUSES BECAUSE OF UNHABITATION
BAD RESTORATION OF THE STONE PAVEMENTS
UNSUFFICIENT SEWAGE SYSTEM


HUMAN MISTAKE
(COOKING WITH GAS IN OPEN AIR)
SUMMER TIME - EVENING
FIRE IN THE BUILDING
FIRE IN THE ADJACENT OPEN SPACE (GRASS)
MINIMUM 10 MIN FOR THE FIRE FIGHTERS TO COME – TURN OFF THE ELECTRICITY
RISK OF DEVELOPMENT OF FIRE IN 4 DIRECTIONS – CRITICAL FOR THE WHOLE BAZAAR AREA
PANIC
TOURISTS EATING IN THE LIGHT OF CANDLES IN THE OTHER RESTAURANTS – RISK OF OTHER FIRES

PREVENTION AND MITIGATION

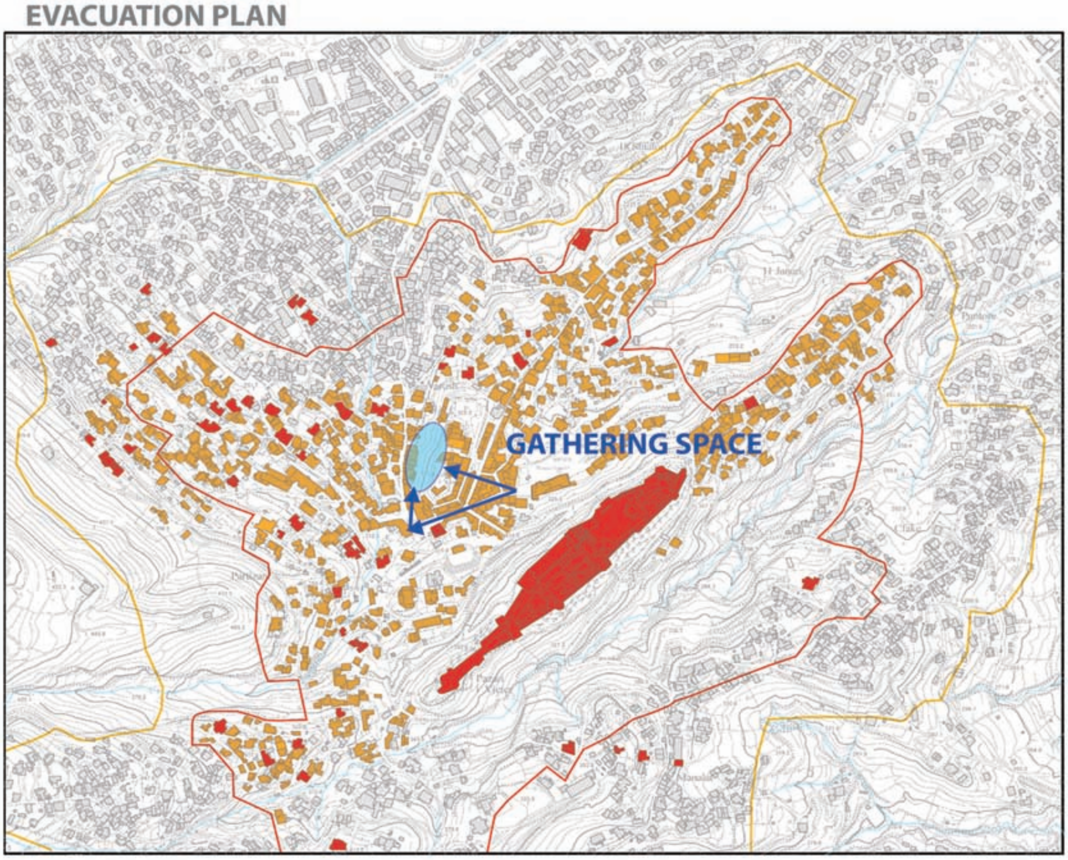
SHORT TERM

FIRE EXTINGUISHERS
SMOKE DETECTORS IN AND OUTSIDE THE BUILDINGS
COMMUNITY AWARENESS OF RISK FROM FIRE

LONG TERM

HIDRANTS IN THE HISTORICAL CENTRE
SPECIAL CONDITIONS FOR GAS USAGE
REGULAR MAINTENANCE OF THE GREEN AREAS

EVACUATION PLAN



RECOVERY AND REHABILITATION

PEOPLE RESCUE

IMMEDIATE DAMAGE ASSESSMENT (RDNC, MUNICIPALITY, UNESCO Office)

IMMEDIATE PROTECTION FOR DAMAGED HERITAGE – INTERVENTION FOR FALLING STRUCTURES (RDNC)

DETAILED DAMAGE ASSESSMENT

PREPARATION OF A PROJECT OF RESTORATION (RDNC, ICM)

RESTORATION

PART II

ASSESSMENT ANALYSIS OF SEISMOLOGICAL RISK AND GEOHAZARD VULNERABILITY OF FIRST LEVEL IN MAJOR CULTURAL HERITAGE SITES OF ALBANIA

1. GEOLOGICAL SETTING AND REGIONAL SEISMIC HAZARD OF ALBANIA

INTRODUCTION

Seismic hazard analysis is the evaluation of potentially damaging-related phenomena to which a region or a facility may be subjected to during its useful lifetime. The cultural sites situated inside an earthquake-prone area are most vulnerable to this kind of natural hazard due to the continuous shaking experienced during the long period of their existence and, as a consequence, gradual loss of their structural stability. The continuous improvement of procedures to define the seismic hazard at the regional, national and local scale is essential for the optimum design of earthquake-resistants structures, and it is one of the tools which permit us to undertake the necessary interventions for their rehabilitation. Reference motion in hard rocks and detailed characterization of soil conditions at each site are the milestones for the appropriate definition of seismic action in cultural heritage sites in Albania.

Before the '90s, the seismic hazard evaluation in Albania was carried out based on the macroseismic intensities of strong historical earthquakes of the 20th century, as well as on seismotectonic synthesis (Sulstarova et al., 1980). Methods used were quite empirical and not based on a rigorous mathematical methodology, although the probabilistic approach (Cornell, 1968) was widely used at that time in other countries, even in the Balkan area. Several attempts have been made in the past few years to express seismic hazard in terms of ground acceleration, velocity and displacement following both deterministic and probabilistic approaches (Muço et al., 2001; Muço et al., 2002; Duni & Kuka, 2003; Duni & Kuka, 2004; Kuka et al., 2003; Aliaj et al., 2004; Fundo et al., 2012).

The probabilistic approach yields a probabilistic description of how likely it is to observe different levels of ground motion at the site, not how likely an earthquake is to occur. Typically, this is given in terms of the annual probability that a given level of ground motion (PGA, SA, intensity, etc.) will be exceeded at a site. Usually, the seismic hazard assessment programs specify a 10% exceedance probability of some threshold of any ground motion parameter, for 50 years of exposure, which corresponds to a 475 year return period. The result can be expressed as a hazard curve giving the annual probability of any level of ground shaking being exceeded at the site of interest, or in the form of hazard maps representing spatial variability of the selected ground motion parameter for a given return period (e.g. 475-year return period).

In this report, first we describe briefly the geodynamic position and the seismicity of Albania. Then we concentrate our attention on the analysis of the seismic hazard of the country, and later on we describe in particular the hazard parameters on hard soil conditions of the major cultural heritage sites, specifically Apollonia, Berat, Butrint, Gjirokastra and Durres.

GEOLOGICAL SETTING AND GEODYNAMICS OF ALBANIA

Geologically, Albania forms part of the Dinaric-Albanic-Hellenic arc of the Alpine orogeny, the formation of which took place mainly in the Tertiary, giving the country its mountainous relief.

On the worldwide zonation, Albania is on the Alpin-Mediterranean seismic belt. This belt comprises the wide zone of contact between the lithospheric plates of Africa and Eurasia, from Azore Islands up to the eastern border of the Mediterranean basin (Fig. 3). In this zone, the concept of plate tectonics is especially complicated because of the presence of numerous blocks and the release of stress through plastic deformation on a large part of

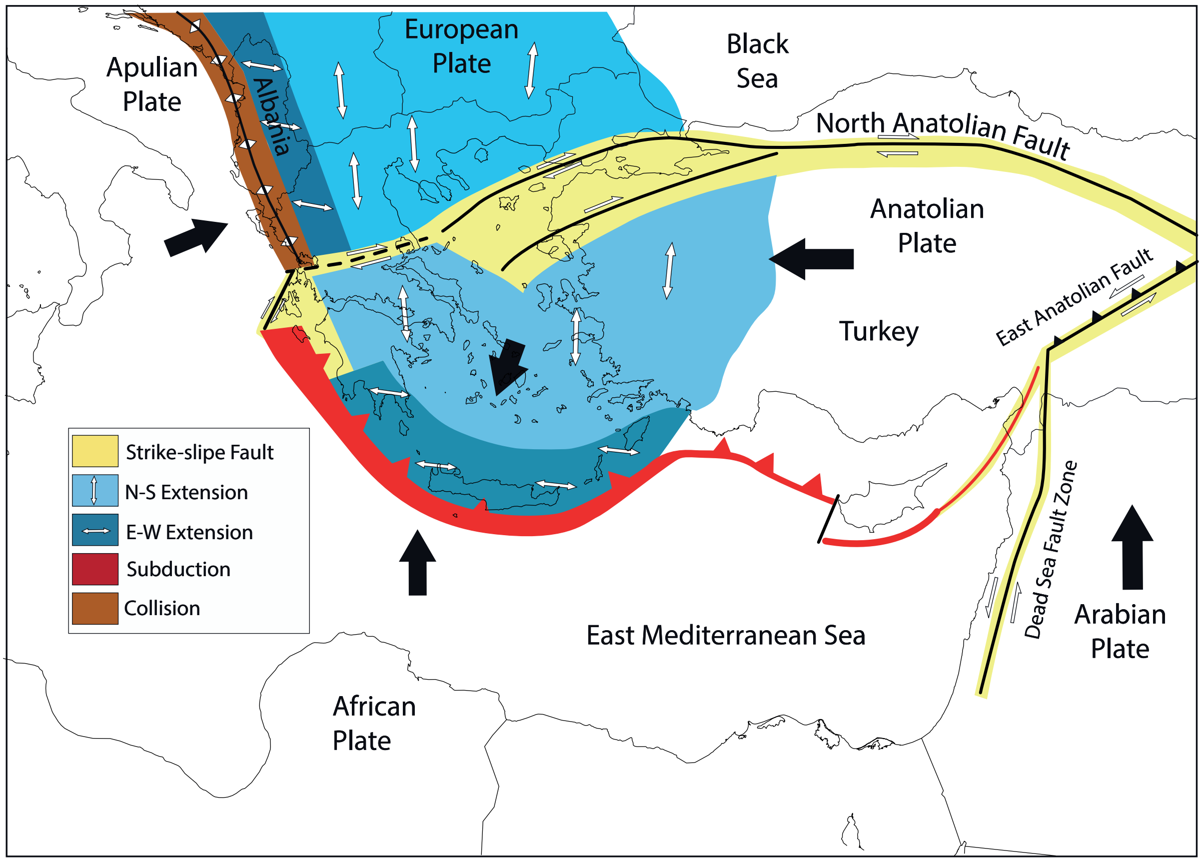


Fig. 3. Schematic geological setting of eastern Mediterranean area (from Papazachos, 1988 and Taymaz et al., 2007, modified).

the zone. The region surrounding Albania comprises a wide tectonic belt with relatively rigid blocks like the Adriatic, some sectors of the Alpine belt, Alps, Carpathes, Balkan Mountains, Dinarides, Helenides, the Helenic Arc and Anatolian belts, as well as internal basins like the Tirren, Egean, Panonia and Black Sea.

Structurally, the mountains are divided into the Internal and External Albanides. The Internal Albanides consist partly of ophiolites, on top of which three sedimentary basins have formed: the small Bajram Curri basin in the north, the Burell basin, and the Korca basin in the south (Fig. 4).

The Internal Albanides are divided into four major thrust tectonic zones, the Mirdita zone (the main ophiolite-bearing zone), the Korabi zone and, in the north, the Alpet-Shqiptare and Gashi zones (Fig. 4).

The External Albanides are divided into three thrust zones, from east to west, the Krasta-Cukali zone, the Kruja zone and the Berati, Kurvaleshi and Cika belts which together form the Ionian zone (Fig. 4). All zones are characterised by carbonate deposition in syn-rift and post-rift settings, covered by flysch.

Two major NE-SW striking lineaments with uncertain origin are present. The northern Shkoder Peje lineament separates the Gashi zone and the Alpet-Shqiptare zone form the rest of the Internal Albanides. The Vlora-Elbasan lineament roughly delineates the northern boundaries of the Cika Belt, Kurvaleshi Belt and Berati Belt of the Ionian zone, and also forms the southern boundary of the Peri-Adriatic Depression.

In the above-mentioned belt, the most active part seismically is the Egean and surrounding zone, where there is Greece, Albania, Montenegro, Macedonia, South Bulgaria and

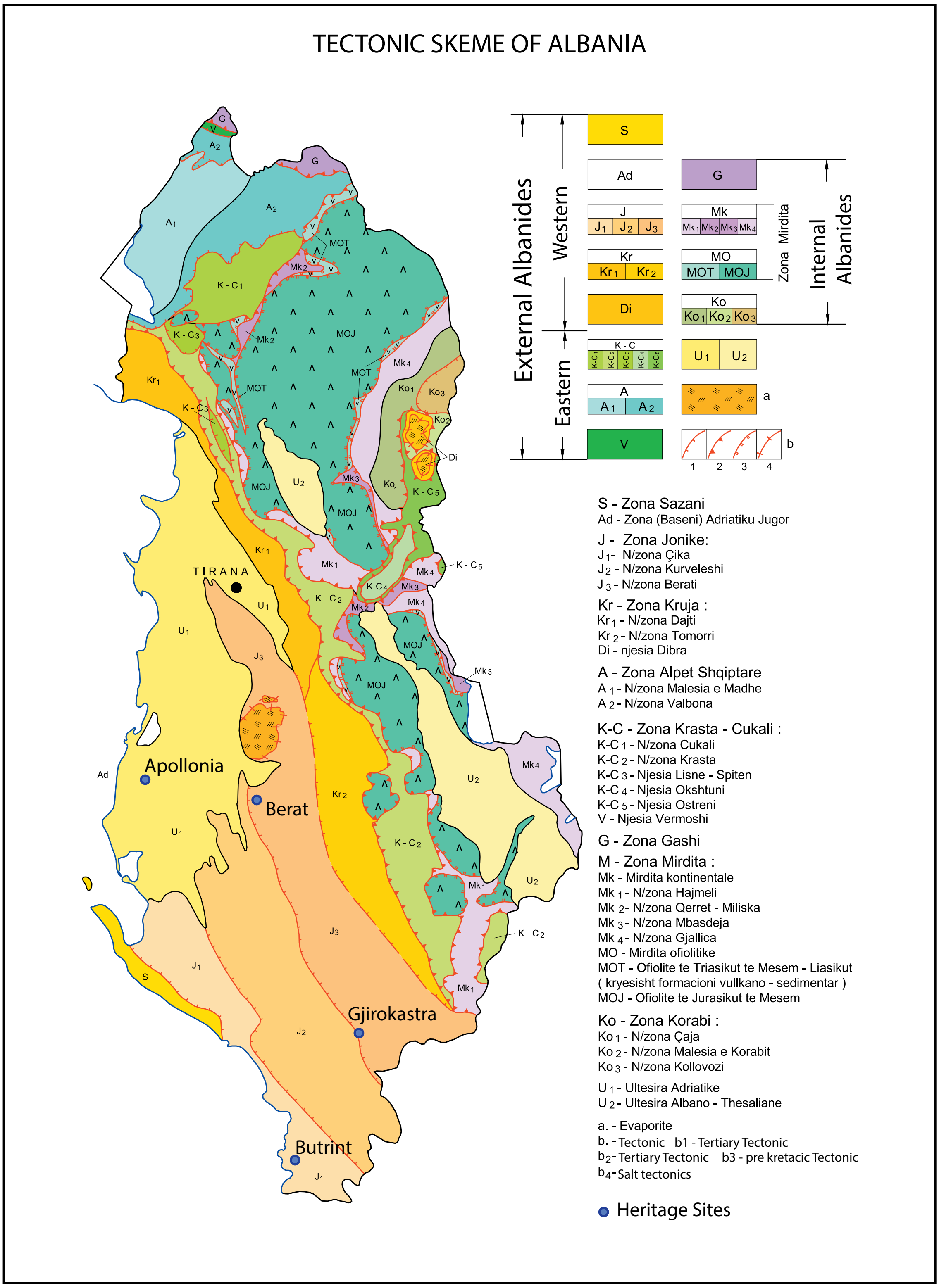


Fig. 4. Tectonic scheme of Albania, the blu points indicate Cultural Heritage sites. (from various authors, Geological Map of Albania, 1:200,000, 2004).

western Turkey.

Almost every year in this part (34-43°N; 18-30°E), at least one earthquake occurs with M > 6.5 (Papazachos, 1988; Taymaz et al., 2007).

Leaving apart the Helenic Arc where the African plate sinks under the Eurasian plate in the subduction form, the other contact between these two plates, and especially that part starting where the western wing of the Helenic Arc already ends and continuing with the western coasts of Balkan peninsula, is implemented through the Adria microplate. This unit acts as a wedge between the Apenines, Alps and Dinarides-Albanides-Helenides mountain ranges.

The origin of the orogenic systems of western Balkan as well as those systems surrounding the Adriatic Sea on the north and west, is strongly connected to the convergence between the Eurasian and African plates (Fig. 3). This process, which began on the Upper Jurassic-Lower Cretaceous, influenced the disappearance of the old ocean Tethys, situated between the two continental margins and whose remnants are today the ophiolites and abyssal sediments on the nappes of the above mentioned orogenic systems.

It is still a matter of dispute whether Adria is today a part of the African plate or should be considered as an independent unit. From the focal mechanism and paleomagnetism studies, it has been revealed that the Adria microplate rotates counterclockwise, with its pole in northern Italy. The conclusions of many studies on the geodynamics and seismicity of the Aegean and generally of eastern Mediterranean region, zones where there is Albania, are converged on the point that mainly the seismicity of Albania is strongly connected to the contact between the Adria and Albanides orogen, which is part of a wider collision between the Eurasian and African plates. This contact, which possibly takes effect through a continental type of collision, unceasingly accumulates deformations and propels the longitudinal tectonic faults bordering it as well as transversal tectonic faults cutting it and penetrating the interior of the peninsula. It is precisely these continuous accumulations of tectonic deformations that through active faults as the earthquake cradles give way to seismic energy release shaping so the seismicity of the country (Fig. 5).

THE SEISMICITY OF ALBANIA

Earthquakes are geological phenomena that clearly demonstrate the dynamics of the planet we live on. They most directly express the enormous energy that the Earth hides inside as a new planet. These phenomena are the causes of sharp changes of the surface of our planet accompanied by its continuous evolution.

As disastrous phenomena, earthquakes have brought great damage to humanity during the centuries. Only during the last 500 years more than seven million people have been killed by earthquakes worldwide and millions more have lost their living resources.

Nevertheless, these phenomena have been not only a source of disasters, but also a valuable source of geological information. The analysis of seismic waves has given detailed and unique information on the internal composition of the Earth.

Earthquakes are unavoidable phenomena and people try to co-exist with them, seeking the most appropriate ways to make them as less dangerous as possible during their time-to-time appearance. The best way to do this to have profound knowledge of these phenomena.

The seismicity of a certain region is defined as a function of earthquake size (magnitude, intensity, seismic moment, etc.), as well as the frequency of their occurrence. On this basis, keeping in mind the well-known classification of earthquakes according their magnitudes (Hagiwara 1964; Lee et.al., 1981), the seismicity of Albania is characterized by an intensive seismic microactivity ($1.0 < M \leq 3.0$), many small earthquakes ($3.0 < M \leq 5.0$), rare medium-sized earthquakes ($5.0 < M \leq 7$), and, very seldom, strong earthquakes ($M > 7.0$).

The seismicity of a country is usually separated into two periods: its historical

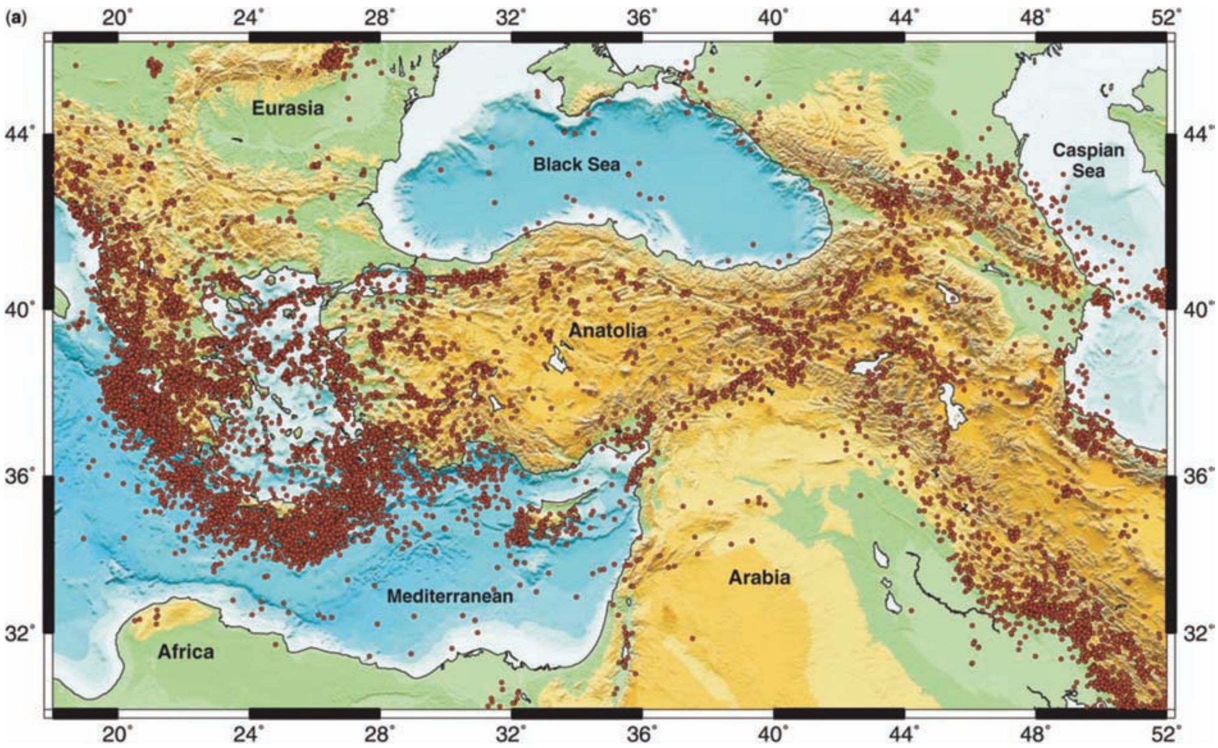


Fig. 5. Seismicity of the eastern Mediterranean region and surroundings reported by USGS–NEIC from 1973-2007 with magnitudes for M > 3 superimposed on a shaded relief map derived from the GTOPO-30 Global Topography Data taken from USGS. Bathymetry data are derived from GEBCO/97–BODC, provided by GEBCO (1997) and Smith & Sandwell, 1997 (from Taymaz et al., 2007).

seismicity and instrumental seismicity. Historical seismicity is based on the information collected from different sources and has to do with that period of history when earthquakes were not yet recorded with special instruments. Instrumental seismicity is identified with the 20th century because from this time in Europe and worldwide the implementation of seismological stations started and earthquake records began to be collected and analyzed systematically.

Historical seismicity

The historical seismicity of Albania is described in some various catalogues like: Mihajlovic, 1951; Shebalin et al., 1974; Sulstarova et al.,1975; Makropoulos et al., 1981; Papazachos & Papazachou, 1989; Papazachos et al., 2000; Guidoboni, 1994; Fundo et al., 2012.

From the evidence we possess today, we can see that from the period of III-II centuries B.C. until the present, Albania has been stricken by 55 strong earthquakes with intensities $I_0 \geq$ VIII degree (MSK-64), of which 15 have had the intensity $I_0 \geq$ IX degree (MSK-64). Of these 55 earthquakes over a period of more than 2000 years, 36 of them belong to the 19th century which makes us believe that the number of disastrous earthquakes we report has been underestimated and other disastrous earthquakes have been hidden in the depths of historical time.

There is reliable evidence that the old town of Durres (Dyrrahum) has been stricken several times by strong earthquakes that have caused serious human and economic losses. From old records we can see that this town was almost totally destroyed in the years 177 B.C., 334 or 345 A.C., 506, 1273, 1279, 1869 and 1870. The evidence for the earthquake of March 1273 says that the town, inhabited by 25 thousand people at that time, was totally destroyed. There were many casualties and the survivors left the town, seeking other places to live. Since this earthquake the importance of Durresi as a port on the Adriatic Sea has diminished.

In the centuries III-II B.C., there is evidence that Apollonia, another ancient town, was struck by strong earthquakes which caused large casualties and damage.

In the year 1153, the town of Butrint (old Buthrot) in the south of Albania, was destroyed by a strong earthquake. Its traces can be found even today on the remnants of this old town.

The town of Berat has been hit by strong earthquakes several times. One of the strongest, well evidenced ones is that of October 17, 1851, which caused a lot of destruction. The fortress of the town was damaged and under its ruins 400 soldiers were buried. This fact demonstrated that there were other victims in town of Berat. Cracks on the ground were observed together with fountains of sand and water mixed together, and a kind of a sulfur dust, which made respiration difficult, was discovered. There were big landslides as well. The highest intensity for this earthquake had to be 9.0 degrees (based mainly on the degree of destruction of the fortress of the town).

Instrumental seismicity

The establishment of seismological stations in Europeon at the end of the 19th and the beginning of the 20th century made it possible to collect evidence of earthquakes in Albania and nearby. Depending on the density and modernization of seismological stations in Europe and worldwide, can say that the earthquakes of Albania and nearby with magnitude $M_S \geq 6.0$ (with intensity $I_o \geq$ VIII degree (MSK-64)), have been recorded by them since the beginning of the 20th century; those with magnitude $M_S \geq 5.5$ (intensity $Io \geq$ VII degree (MSK-64)) since 1911; those with $M_S >$ 5.0 (intensity $I_o >$ VI degree (MSK-64)) since 1940; those with $M_L \geq 4.0$ (intensity $I_o \geq$ IV-V degree (MSK-64)) since 1968, and those with magnitude $M_L \geq 2.5$ since 1976.

The first seismological station in Albania was set up in August 1968, while the Albanian Seismological Network (ASN) started in 1975. The ASN is presently composed of 13 stations equipped with various digital instruments. A new, fully integrated digital seismograph system using the satellite communication (VSAT) is now under operation as part of ASN. Seven satellite remote stations have been installed on SRN, PHP, KBN, BCI, PUK, TIR and VLO and transmit continuous data in real time. The Libra satellite seismograph system includes a central VSAT Hub (Libra Nanometrics) running the NaqsServer acquisition software and 7 Cygnus remote sites configured to acquire respectively the three-component broadband stations (Trillium 40T and CMG-40T) equipped with 24 bits digitizers (Trident).

From the collected and processed data it is proven that during the 20th century Albania was hit by many damaging earthquakes. A real picture of the seismicity of Albania can be clearly seen from Fig. 6.

INPUT FOR SEISMIC HAZARD ASSESSMENT

Earthquake Catalog

Seismicity studies depend largely on the available information, as well as completeness and reliability of earthquake data expressed in the earthquake catalog used. The bulk of our knowledge of past seismicity relies on the historical record of earthquake damage. In the early 20th century, recording of the waves released by earthquakes in order to achieve a precise determination of hypocentral locations and magnitudes began. Instrumental observations complement the macroseismic observations for larger events, and are the basis for a homogenous record of the seismicity in Albania since 1968.

A homogenous earthquake catalog for Albania was compiled in 1975 and was revised during the period 2000-2005 (Kuka et al., 2005). It contains about 700 earthquakes with a

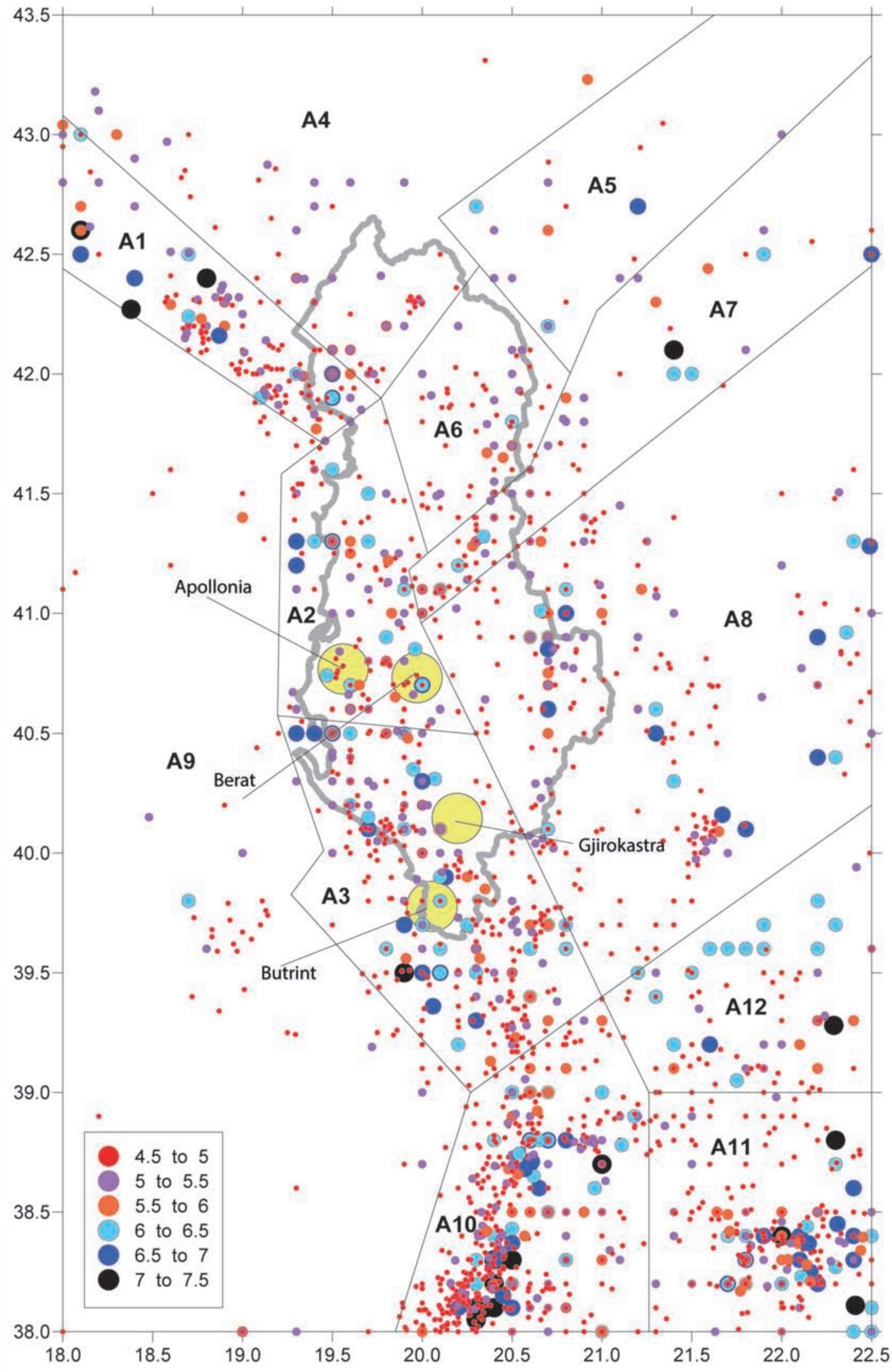


Fig. 6. Historical and instrumental seismicity in Albania and surroundings (time span: 550 B.C. to 2010, $M_W \geq 4.5$), and seismotectonic zonation used for PSHA.

magnitude greater than or equal to 4.5. The catalog covers a time span from the year 58 B.C. up to 2005, and an area between 18.5°-21.5°E and 39-43°N. The size of the earthquakes is given in terms of surface-wave magnitude M_S.

For a better assessment of seismic hazard, a seismicity-working file has been compiled, revising the above catalog, and extending its geographical borders by at least 1 degree, also including events from the neighboring areas. The working file has been produced by cautiously merging the above catalog with the ISC bulletins for the period 1964-2010, and the Skopje and Thessaloniki earthquake catalogs. When different catalogs have different interpretations of an event, the highest priority is generally given to the catalog of the country where the event occurred.

Moment magnitude, M_W, has been chosen as the common measure of earthquake size for both historically known and instrumentally recorded events. In the Thessaloniki catalog (Papazachos et al., 2000) earthquake size is expressed in moment magnitude M_W scale; ISC bulletins report M_W and M, whereas Tirana and Skopje use the M_S scale. Magnitudes M_S and mb are converted to M_W using the relevant formulas (Scordilis, 2006). Finally, earthquake data files used in further steps comprises a total of about 2300 events with $M_W \geq 4.5$. It covers the time period from 550 B.C. up to December 31, 2010 and the area between 18.0-22.5°E and 38-43.5°N. A map which depicts the spatial distribution of epicenters of earthquakes used in the present study is demonstrated in Fig. 6. It is obvious that seismicity is not uniformly distributed within the country.

Data completeness with time

The modeling of seismicity in every zone needs estimation of the recurrence parameters, a and b in the Gutenberg-Richter (G-R) relation $logN = a-bM$, where N is the cumulative number of events, the a-value the productivity of a volume, and the b-value the relative size distribution.

Its estimation is critically dependent on the correct identification of the magnitude of completeness, below which only a fraction of all events in a magnitude bin are detected. In other words, we need to verify and account for the degree of correspondence of the apparent seismicity, as indicated by the catalog, with actual seismicity, i.e. what actually takes place. Completeness as a function of space and time varies first of all, country-by-country, according to geographical and cultural-historical aspects which obviously influence the data compilation.

An analysis of the completeness of the catalog has been performed by using the cumulative number of events *versus* time graphs, in order to evidence slope changes, assuming that the most recent change in slope occurred when the data became complete for magnitudes above the reference (Gasperini et al., 2000). The completeness test was performed for M_W in half magnitude classes. By making use of the cumulative number *versus* time graphs, we have identified four magnitude intervals, the point in time from when the data is assumed to be complete. The catalogue described above can be considered complete for $M_W \geq 4.5$ since 1955, for $M_W \geq 5.0$ since 1905, for $M_W \geq 5.5$ since 1850 and $M_W \geq 6.0$ since at least 1550 (Fig. 7).

Declustering the catalog

For most hazard-related studies, the seismicity must behave in a time-independent fashion in order to avoid biasing the average-rate assessments with data from, for example, prominent aftershock sequences that may not be representative of the average behavior of a crustal volume. To model earthquake occurrence in time, it is assumed that they follow a Poisson process with constant recurrence rate g. Declustering attempts to separate the time-independent part of seismicity (background) from the time-dependent or clustered parts (aftershocks, foreshocks and swarm type activity).

First, we investigated whether or not the temporal distribution of events within our

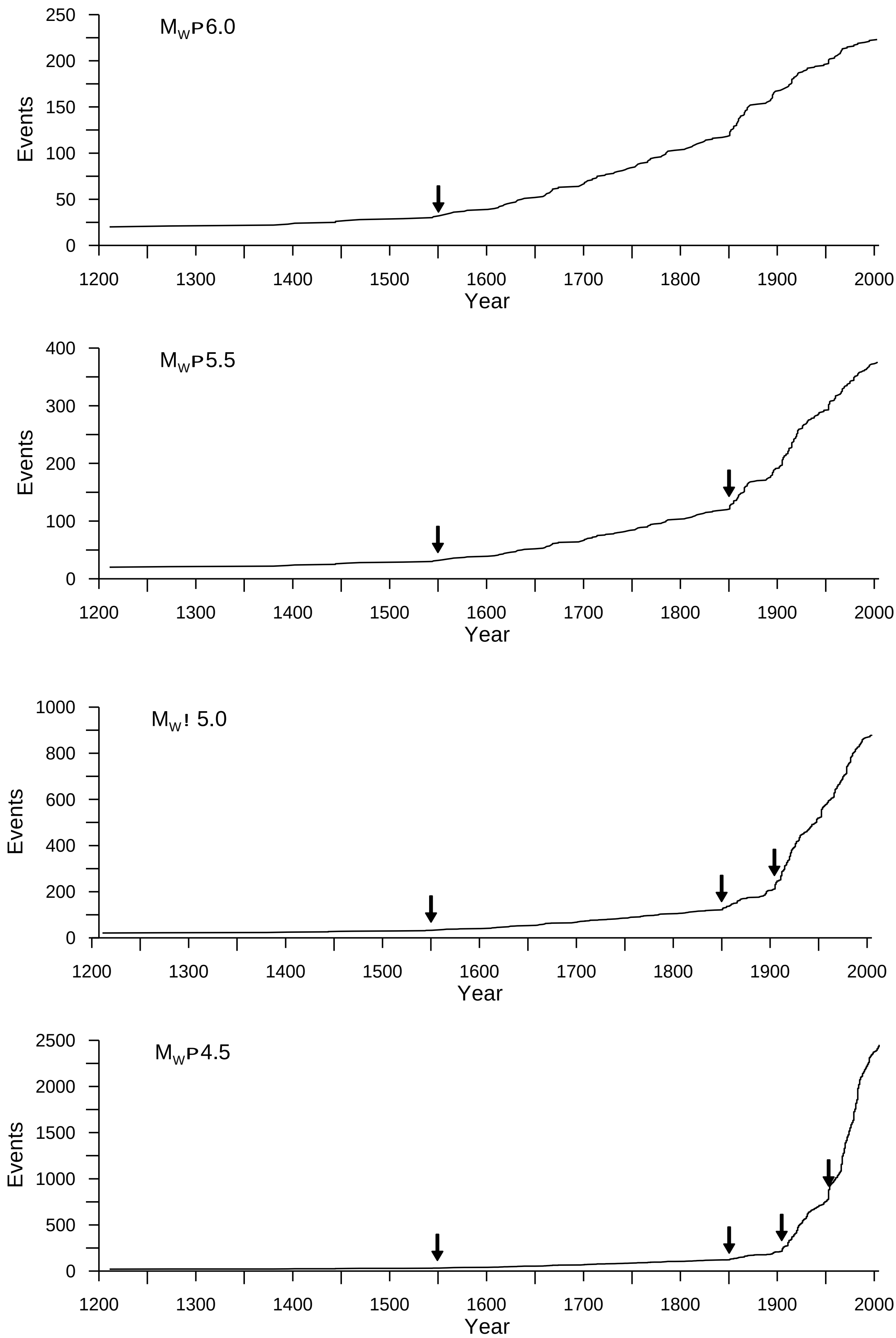


Fig. 7. Cumulative number of seismic events versus magnitude M ≥ 4.5, 5.0, 5.5 and 6.0; the arrows indicate the points where the slope of the curve changes.

catalog is Poissonian, which would argue that declustering may not be necessary. For the evaluation of the earthquake occurrence, the Weibull distribution for the time interval between successive events, T is used very often, with hazard function:

$$h(t) = t^{1/\rho-1}$$

where the hazard profile is determined by the $t^{1/\rho-1}$ element. If $\rho = 1$, hazard is uniform and this is the case of the Poissonian process; if $\rho < 1$, hazard is increasing; and if $\rho > 1$, hazard is diminishing with time.

So investigating the time interval T between successive events by using the Weibull distribution for T, we found that the process cannot be considered as a Poissonian one. Therefore, the catalog has to be purged of aftershocks and foreshocks prior to modeling the magnitude frequency distribution and any further analysis.

The seismicity data file was made Poissonian by tagging the main shocks and applying a distance-window and two time-windows simultaneously for eliminate foreshocks and aftershocks. The window parameters are dependent on the main shock magnitudes. Using a space time magnitude dependent window, we identified 1171 independent events and removed all aftershocks and foreshocks from the sample. The estimate of the ρ parameter, for all the data groups I-IV, I (events with $M_W \geq 4.5$, 1955-2010), II ($M_W \geq 5.0$, 1905-2010), III ($M_W \geq 5.5$, 1850-2010) and IV ($M_W \geq 6.0$, 1550-2010) are already near the value 1 (Figs. 8 and 9). In Fig. 9 it is clearly seen that the difference between the exponential and Weibull distributions is narrowed. This new subcatalog, purged of aftershocks and foreshocks, is used to adequately estimate the seismicity parameters, and in other calculations for seismic hazard assessment.

Estimating seismicity parameters

The parameters currently used for quantitative evaluation of seismicity are the well-known statistics which define the magnitude-frequency relation G-R, such as the mean annual rate λ, the b-value of the G-R relation, the completeness threshold of seismic data, M_{min}, above which the catalog is considered to be complete, and the maximum possible magnitude M_{max}. The reliable estimation of these parameters is of primary importance because evaluation of the seismicity rate in a region is directly dependent on them. We used a maximum likelihood approach for their estimation, as outlined in Bollinger et al. (1993), Weichert (1980), and Berril and Davis (1980). This method is considered more appropriate than the least squares to determine the recurrence parameters, because all available data is weighted appropriately, taking into account the data sets of variable completeness with time.

Another approach to estimate the seismicity parameters is that of Kijko-Selevoll (Kijko and Selevoll, 1989), which considers not only the recent instrumental data, but also the historical macroseismic events that occurred over a period of more than two thousands years. In addition, the uncertainties in earthquake magnitude can also be considered. Mean activity rate λ, G-R b-value, and the maximum regional magnitude M_{max} are estimated using the maximum likelihood procedure by applying the Bayesian formalism.

First, based on a model proposed before (Kuka et al., 2004), a seismotectonic model was defined consisting only of polygonal zones of assumed distributed seismicity (Fig. 6). The main zones were defined to have similar geodynamic behavior and a rather homogenous distribution of seismicity. Each zone is characterized by a frequency-magnitude distribution, which is derived from joint historical and instrumental seismicity data. We estimated the overall recurrence parameters for all events within Albania and about 100 km of the Albanian border (Fig. 6). Then the recurrence parameters in each zone were also estimated using the same methodology; results are shown in Table 3. Comparing the estimates

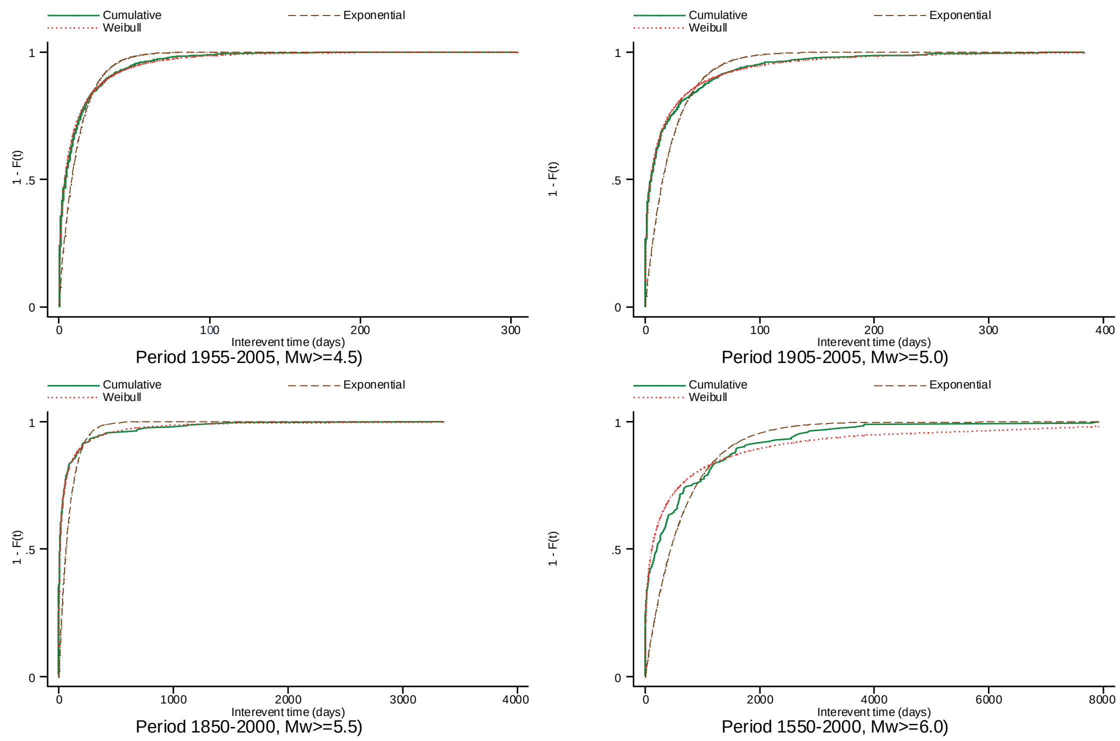


Fig. 8. Cumulative distribution of the time interval between events, T and the S(t) curve (the so-called survival curve) for the exponential and Weibull distributions (including foreshocks and aftershocks).

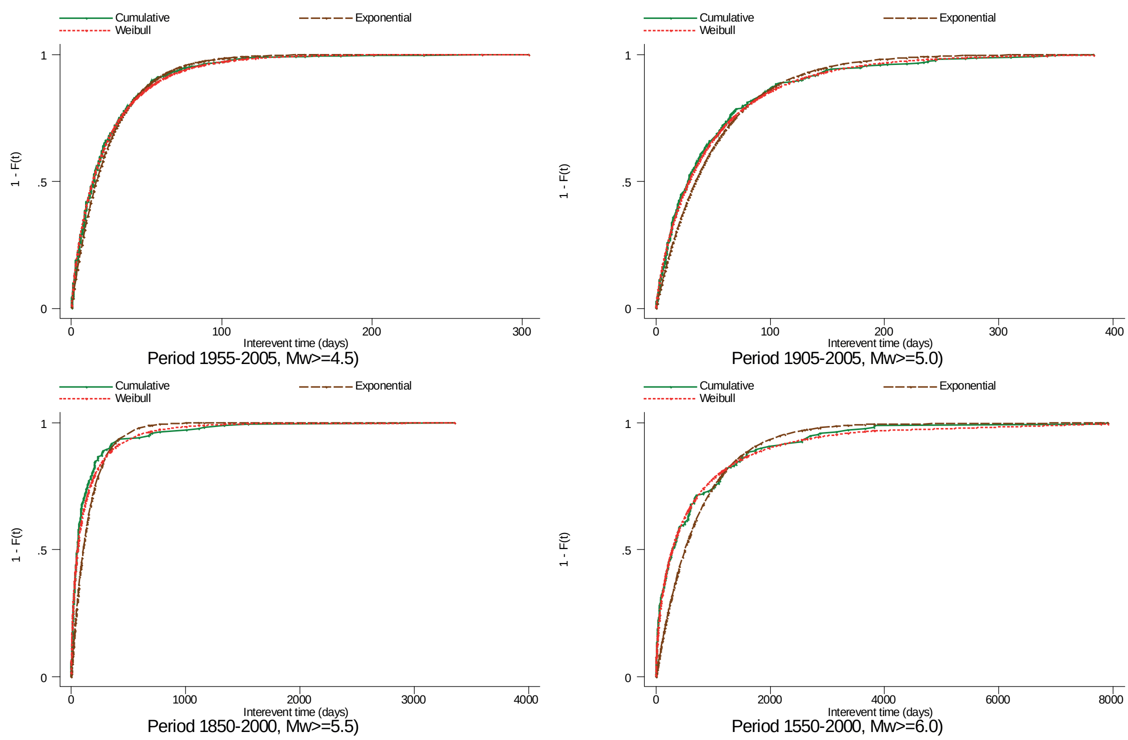


Fig. 9. Cumulative distribution of the time interval between events, T and the S(t) curve (the so-called survival curve) for the exponential and Weibull distributions (after removing the foreshocks and aftershocks).

taken by the two approaches doesn't indicate any remarkable difference.

Using the parametric-historic procedure of Kijko, 2004, we also calculated the hazard curves (probabilities of exceedance of specified value of magnitude) for the region (19.0°-21.2°E, 39.5°-42.7N°) which comprises the Albanian territory. Results are shown in Table 4.

We can see that the mean rate of occurrence (return period) for earthquakes with M_W = 5.0, 5.5, 6.0, 6.5 and 6.8 are respectively 0.7, 3.1, 14.1, 71.6 and 252 years, while one earthquake with M_W = 7.0 could be repeated every 1213 years. From the probabilistic point of view, with 97% probability we have to expect one earthquake with a magnitude of up to 6.0 every 50 years; and with 75% probability, one earthquake with magnitude of up to 6.5 every century.

The maximum possible earthquake, M_{max}, is recognized as a critical parameter with considerable influence on the final hazard, at

Table 3. Recurrence parameters estimated by Bollinger et al., and Kijko-Selevoll approaches.

Source zone	Number of events	M_{max} (obs)	Bollinger et al. *a*-value	Bollinger et al. *b*-value	Bollinger et al. l(M_w≥4.5)	Kijko-Selevoll *b*-value	Kijko-Selevoll λ(M_w≥4.5)	Kijko-Selevoll M^*_{max}	M_{max} PSHA
A1	52	7.2	3.796 ±0.111	0.899 ±0.021	0.564 ±0.051	0.90 ±.06	0.54 ±.05	7.26 ±0.12	7.25
A2	70	6.8	4.733 ±0.116	1.064 ±0.022	0.880 ±0.060	1.08 ±.09	0.72 ± .09	6.85 ±.11	6.90
A3	224	7.0	5.878 ±0.486	1.198 ±0.096	3.082 ±0.067	1.45 ±.07	2.74 ±.22	7.06 ±.12	7.00
A4	35	5.9	6.054 ±0.210	1.406 ±0.043	0.533 ±0.078	1.32 ±.21	0.50 ± .09	6.15 ±.27	6.20
A5	13	6.7	4.049 ±0.269	1.074 ±0.052	0.165 ±0.060	1.16 ±.16	.17 ± .03	6.90 ±.22	6.80
A6	37	6.1	5.849 ±0.198	1.357 ±0.040	0.552 ±0.076	1.13 ±.19	0.54 ± .09	6.50 ±.41	6.80
A7	50	7.0	4.636 ±0.132	1.074 ±0.026	0.634 ±0.061	1.30 ± .11	0.49 ±.08	7.20 ± .22	7.10
A8	147	6.7	6.255 ±0.359	1.316 ±0.072	2.152 ±0.074	1.48 ±.08	1.84 ± .16	6.75 ± .11	6.80
A9	40	6.0	7.686 ±2.921	1.746 ±0.615	0.673 ±0.093	1.88 ± .00	0.60 ±.01	6.06 ±.12	6.10
A10	216	7.4	5.355 ±0.207	1.092 ±0.040	2.773 ±0.062	1.16 ± .06	2.61 ±.21	7.45 ±.11	7.40
A11	144	7.0	5.561 ±0.250	1.171 ±0.061	1.950 ±0.066	1.35 ±.07	1.79 ±.16	7.06 ± .12	7.10
A12	49	7.0	4.517 ±0.199	1.051 ±0.038	0.610 ±0.059	1.02 ± .06	0.61 ±.05	7.06 ± .12	7.10
Albania	512	7.0	6.082 ±0.069	1.171 ±0.014	6.471 ±0.067	1.27 ±0.04	6.04 ±0.29	7.08 ±0.13	7.20
Study area	1037	7.4	6.412 ±0.109	1.170 ±0.022	14.030 ±0.066	1.24 ± .02	6.16 ±.19	7.43 ± .10	

Table 4. Earthquake return periods (RP) for different magnitudes for Albanian territory.

M_W	Lambda	Return period	Probability			
			T=1	T=50	T=100	T=1000
5.0	0.139E+01	0.7 (0.7, 0.8)	0.750953	1.000000	1.000000	1.000000
5.1	0.104E+01	1.0 (0.9, 1.0)	0.645067	1.000000	1.000000	1.000000
5.2	0.772E+00	1.3 (1.2, 1.4)	0.537741	1.000000	1.000000	1.000000
5.3	0.575E+00	1.7 (1.7, 1.8)	0.437080	1.000000	1.000000	1.000000
5.4	0.428E+00	2.3 (2.2, 2.5)	0.347996	1.000000	1.000000	1.000000
5.5	0.318E+00	3.1 (3.0, 3.3)	0.272507	1.000000	1.000000	1.000000
5.6	0.236E+00	4.2 (4.0, 4.4)	0.210579	0.999993	1.000000	1.000000
5.7	0.176E+00	5.7 (5.4, 6.0)	0.160991	0.999846	1.000000	1.000000
5.8	0.130E+00	7.7 (7.3, 8.1)	0.121997	0.998504	0.999998	1.000000
5.9	0.962E-01	10.4 (9.9, 10.9)	0.091743	0.991864	0.999934	1.000000
6.0	0.710E-01	14.1 (13.4, 14.8)	0.068507	0.971227	0.999172	1.000000
6.1	0.521E-01	19.2 (18.3, 20.2)	0.050793	0.926200	0.994554	1.000000
6.2	0.381E-01	26.3 (25.0, 27.6)	0.037364	0.851029	0.977808	1.000000
6.3	0.276E-01	36.2 (34.5, 38.1)	0.027227	0.748478	0.936736	1.000000
6.4	0.198E-01	50.5 (48.2, 53.1)	0.019598	0.628289	0.861831	1.000000
6.5	0.140E-01	71.6 (68.3, 75.2)	0.013870	0.502607	0.752601	0.999999
6.6	0.962E-02	103.9 (99.1, 09.2)	0.009577	0.381946	0.618009	0.999934
6.7	0.638E-02	156.6 (149.4, 164.6)	0.006364	0.273280	0.471878	0.998312
6.8	0.397E-02	252.0 (240.3, 264.8)	0.003961	0.179987	0.327579	0.981102
6.9	0.217E-02	461.4 (440.0, 485.0)	0.002165	0.102705	0.194861	0.885526
7.0	0.824E-03	1213.2 (1157.0, 1275.1)	0.000824	0.040370	0.079111	0.561395

least for the long return period. The seismicity parameter is the most difficult to assess because the physical understanding of M_{max} is poor and the database to derive this parameter is statistically very limited. We used the Kijko-Selevoll approach based on observed seismicity, also considering the previous estimates based on geological consideration (Aliaj et al., 2004). The overall (area shown in the Fig. 6) maximum observed historical magnitude is 7.4, whereas the maximum observed magnitude for zone *A2,* which comprises Tirana, is 6.9. The Kijko-Selevoll estimates for M_{max} seem to be reasonable, accounting for the long return periods of large earthquakes on the Albanian territory. The last column of Table 3 presents the M_{max} value, for every source zone used in our hazard calculations.

The standard G-R recurrence relationship covers an infinite range of earthquakes, and may produce earthquake magnitudes that are physically not possible. Therefore, bounded G-R recurrence law has been proposed to confine the range of magnitudes to eliminate the contribution of very small earthquakes at the lower end and unrealistic high magnitude earthquakes at the high end. The lower limit has been limited to a lower threshold magnitude, M_{min}, under which earthquakes have negligible influence on structures. The high end of the recurrence law is also bounded by M_{max}, representing the maximum magnitude that can occur at the source. Fig. 10 shows our fitting of the overall double-truncated exponential recurrence relationship, with *b* value equal to 1.17 and M_{max} = 7.4. The good agreement between the model and the observation data is obvious, and it gives high credibility to the recurrence law.

PREDICTIVE GROUND-MOTION MODELS

Ground-motion relations, which estimate peak ground motion as a function of earthquake magnitude and distance, are generally the parameter with the largest influence to seismic hazard assessment. Predictive ground-motion models are usually developed from the statistical analysis of strong-motion records available. Due to the absence of strong-motion data, an adequate attenuation model is not available for Albania so far. So we have to consider models of attenuation from regions surrounding our country, or models accepted and used worldwide. A number of ground-motion relations have been proposed for Europe (Sabetta and Pugliese, 1996; Ambraseys et al., 1996). However the magnitude scale used in these models is M_S. Converting the catalog to M_S is easy, but that would add additional uncertainty. In 2002, Margaris et al. proposed a new attenuation model derived from the Greek data and adjacent areas, from mainly normal faulting earthquakes of magnitudes ranging from 4.5 to 7.0. Unfortunately, this model is limited to PGA. A comparison of these predictive models is shown in Fig. 11.

Recently, Ambraseys et al. (2005), utilizing a large and uniform dataset of strong-motion records from Europe and the Middle East, derived new predictive ground-motion models for the estimation of ground motion caused by shallow crustal earthquakes, for PGA and

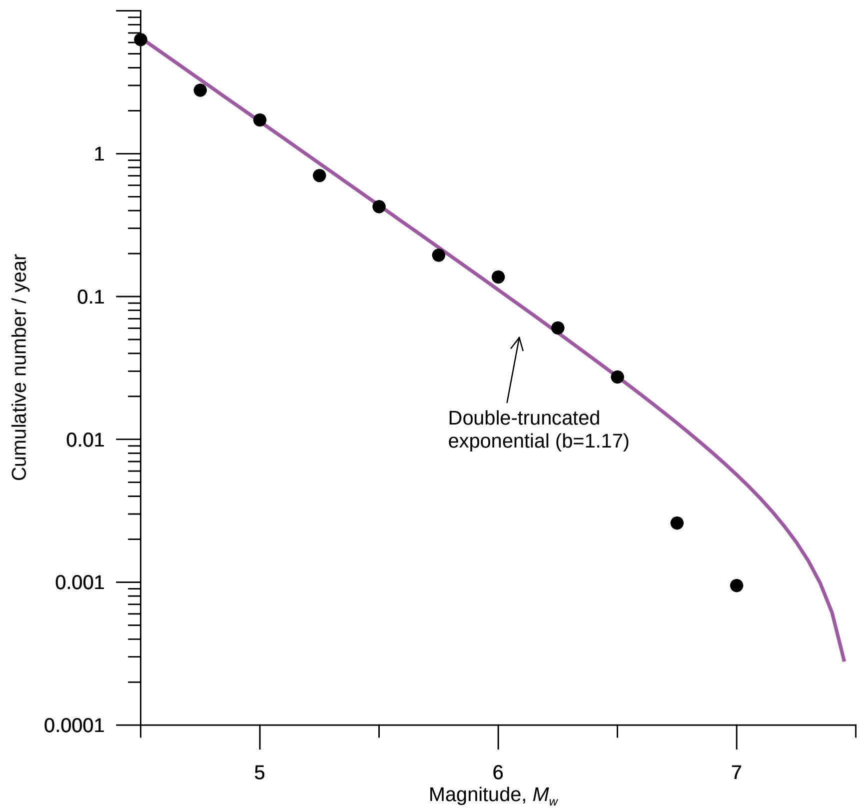


Fig. 10. Overall Magnitude-Frequency relationship.

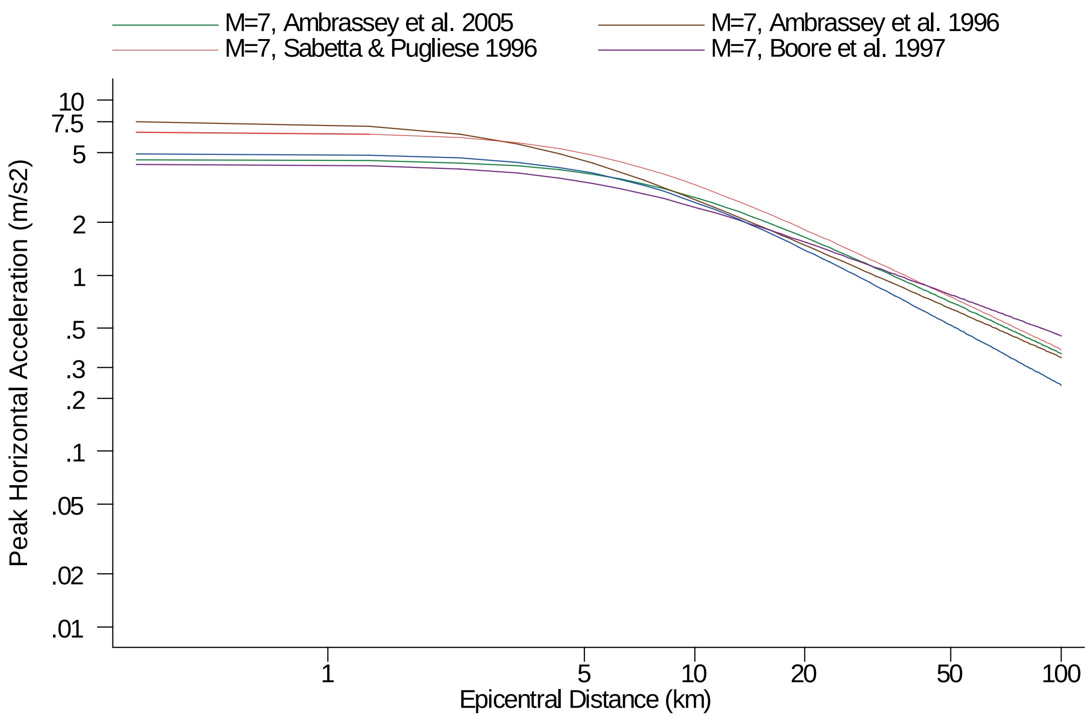


Fig. 11. Comparison of the estimated median PGA (rock) given by some well-known relations.

spectral accelerations for a wide range of periods, with magnitudes $M_W \geq 5.0$ and distance to the surface projection of the fault less than 100 km. We intensively tested this model in hazard computations, but the results were fully unrealistic for PGA and SA < 0.95 s. We think that is due to heteroscadisticity of the relevant models, which use a magnitude-dependent standard deviation for their equations.

Considering the above-mentioned problems, we decided to use the well-known model of Boore et al. (1997), which was created for shallow earthquakes, using the same magnitude scale and distance metric as Ambraseys et al. (2005). According to Ambraseys et al. (2005), for moderate and large earthquakes, predicted PGA and SA from their equations are not much different than those predicted by the ground-motion equations of Boore et al. (1997). Because Boore et al. (1997) use a constant standard deviation for their equations, we decided to use these ground-motion relations as predictive ground-motion models in the seismic hazard assessment.

HAZARD COMPUTATION AND RESULTS

Seismic hazard analysis is commonly performed to provide a quantitative estimation of earthquake hazard at a specific site, thus providing the necessary design ground-motion parameters. Depending on the methodology of characterizing the hazard, seismic hazard analysis is referred to as a) deterministic (DSHA) or b) probabilistic seismic hazard analysis (PSHA). In deterministic seismic hazard analysis, the ground-motion characteristics are determined by choosing a controlling earthquake scenario and estimating the corresponding ground-motion parameters. PSHA provides a framework in which uncertainties in size, location, and rate of recurrence of earthquakes, and variation of the ground-motion characteristics with magnitude size and location can be considered in the evaluation of seismic hazard by relating the ground-motion parameter with average return period. The main benefit of the PSHA is that it allows computation of the mean annual rate of exceedance of a ground-motion parameter at a particular site based on the aggregate risk from potential earthquakes of many different magnitudes occurring at many different source-site distances.

Of various probabilistic methods in use, we chose the spatially smoothed seismicity approach, developed by Frankel (1995) and widely used in the USA today (Frankel et al., 2000, 2002; Petersen et al. 2008). The method still follows the basic approach established by Cornell in 1968, but no delineation of seismic sources is needed. The observed area is divided into grid cells, and in each cell the activity rate (the number of earthquakes above the threshold magnitude) is calculated and then spatially smoothed with a Gaussian function. The annual rate of exceedance of the specified level for a given ground-motion parameter and the relevant value corresponding to a given return period are calculated. The adopted approach considers different alternatives about fundamental hypothesis on input parameters to account for and to propagate uncertainties in the model within a logic-tree framework.

Probabilistic seismic hazard maps

There is not, in fact, a single parameter which adequately represents complete information of seismic hazard. The most popular parameter is peak ground acceleration (PGA), but it is generally associated with a short impulse of very high frequency and, therefore, cannot be easily correlated to the damage observed. For these reasons, spectral response accelerations (SA) for a range of periods with engineering interest have to be considered as well. The SA 0.2 s is especially important, because it corresponds to the portion of the spectrum where local soil conditions are likely to enhance seismic motion and to the resonance frequency of two- to five-story buildings, which represent the largest contributor to the building stock in Albania.

PSHA was performed for the entire Albanian territory for return periods of 95, 475, 975, 2475 and 5000 years, corresponding to probabilities of exceedance of 10% in 10 years, and 10%, 5%, 2% and 1% respectively, in 50 years. PGA and spectral accelerations SA 10, 5, 3.3, 2, 1, and 0.5 Hz have been targeted in our study.

The seismic hazard was calculated for a grid of points with a spacing of 0.05 degrees in latitude and longitude, for a total number of 9900 computation nodes, which cover the entire area (18.0°-22.5°E, 38.0°-43.5°N). The acceleration values contoured are the maximum horizontal component. The reference- site condition is firm rock, defined as having an average shear-wave velocity of 760 m/sec in the top 30 meters, corresponding site class A of the Eurocode 8 provisions.

The doubly-truncated exponential GR recurrence relation is used, with lower-bound magnitude $M_W = 4.5$ for all zones, and upper-bound magnitude M_{max} different for each zone, according to Table 3. The maximum distance applied in the computation is 100 km. As a predictive ground-motion model, we used that of Boore et al. (1997).

Probabilistic seismic-hazard maps were prepared for the Albanian territory portraying PGA with probabilities of exceedance of 10% in 10 years and 10% in 50 years. Aside from these PSHA maps, site-specific PSHA parameters (PGA and SA) for different return periods for Berat, Gjirokastrër, Butrint, Apollonia and Durrësi have also been performed.

The seismic-hazard assessments results (Figs. 12 and 13) indicate that very few areas can be considered as moderate hazard zones (PGA < 0.24 g) according to the GSHAP project classification. Acceleration ranges from approximately 0.25 g in the entire territory, up to 0.33 g in the southwestern part (Himara) of the country, with a 10% probability of exceedance in 50 years. The lowest hazard is observed in northern Albania, where values less than 0.20 are expected. The northwestern part of the country (Shkodra), Tirana-Durres belt, Lushnja-Elbasan-Dibra area, and Pogradec-Korça area also reveal a high hazard, with PGA greater than 0.27 g.

A comparison with PSHA in neighboring

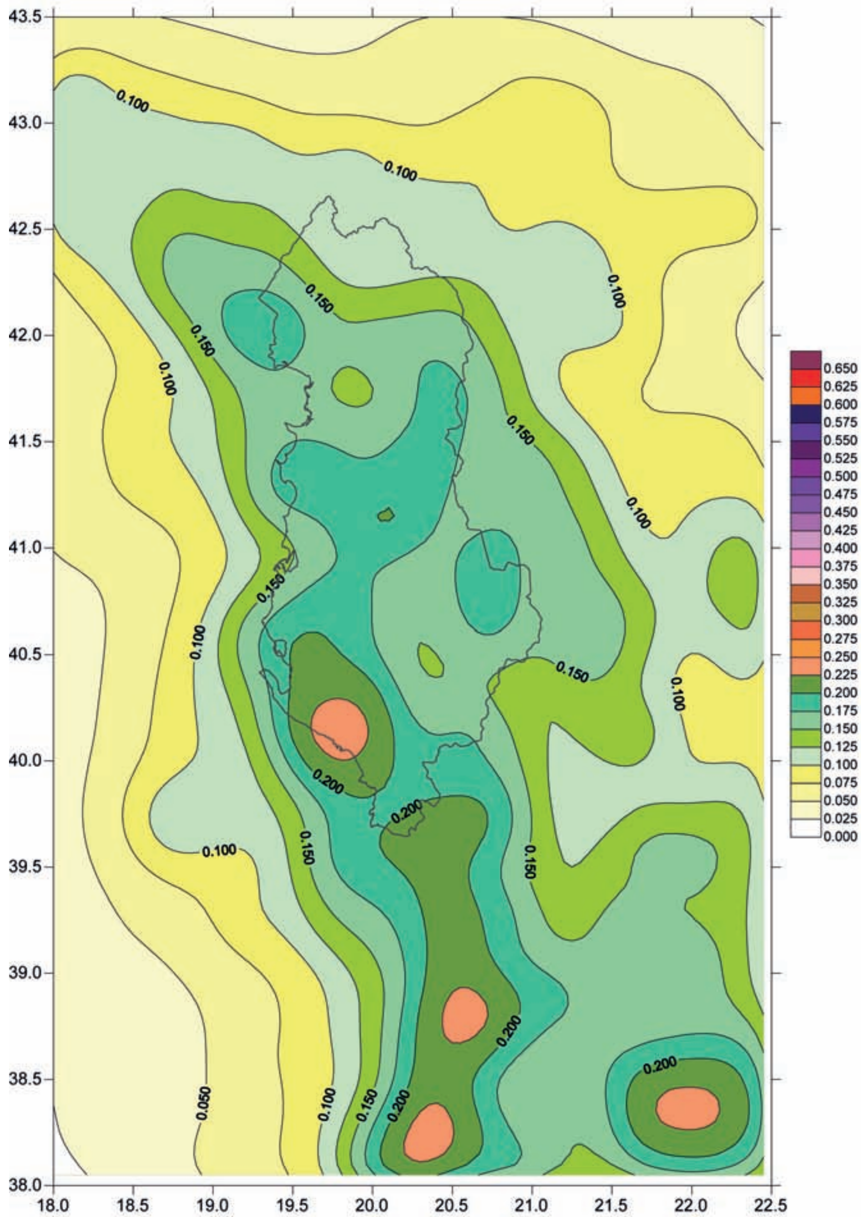


Fig. 12. Probabilistic seismic hazard map of Albania for PGA with return period 95 years (10% probability of exceedance in 10 years); attenuation relation: Boore et al. 1997, rock condition.

countries shows a good consistency with their results. In particular, a comparison with the Greek zonation map shows a good similarity, both in terms of PGA values and shape of corresponding zones in the border region between the two countries.

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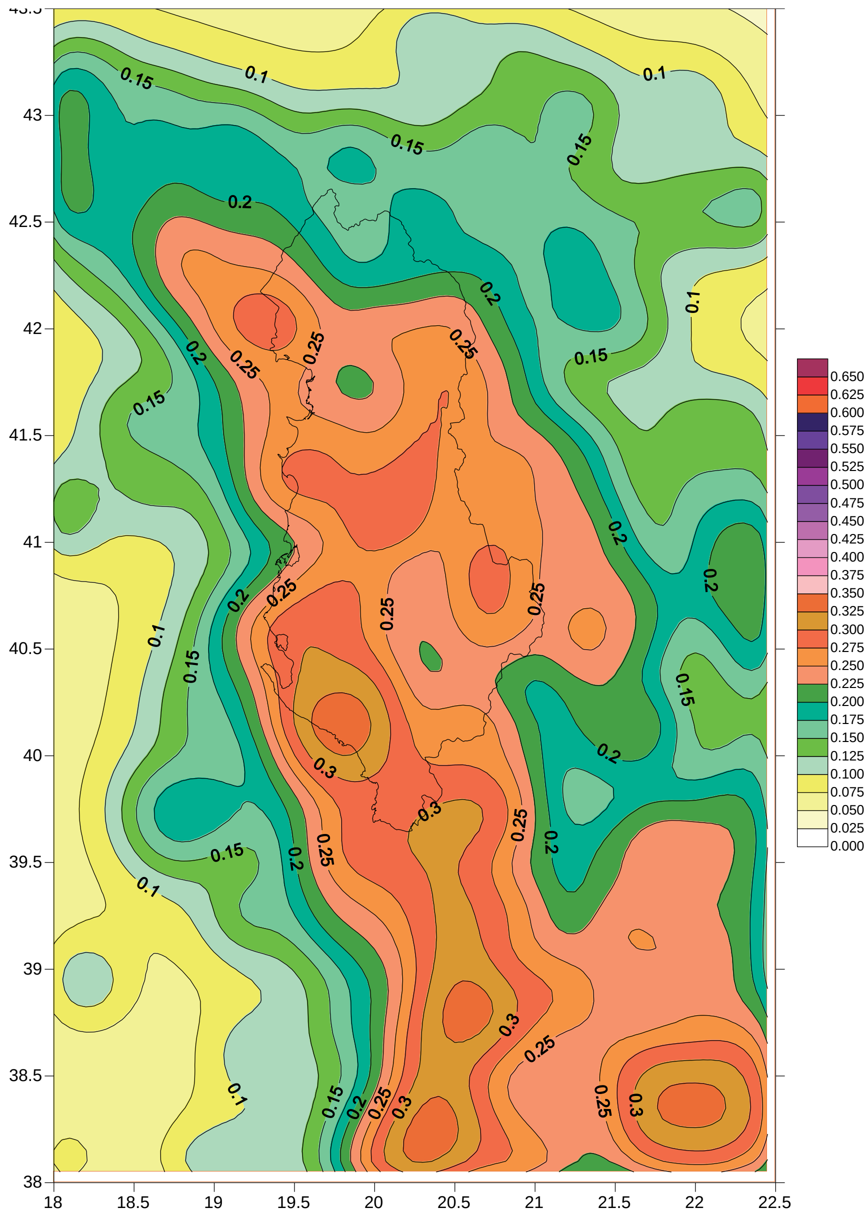

Fig. 13. Probabilistic seismic hazard map of Albania for PGA with return period 475 years (10% probability of exceedance in 50 years); attenuation relation: Boore et al. 1997, rock condition.

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2. GEOPHYSICAL INVESTIGATION OF THE ALBANIAN CULTURAL HERITAGE SITES

INTRODUCTION

Under the UNESCO project "Building Capacity in Natural Risk Preparedness for Cultural Heritage Sites in Albania", we performed geophysical measurements in order to lead to for a further investigation of the soil conditions in Berat, Gjirokastra, Butrint and Apollonia Cultural Heritage Sites of Albania.

The scope of the study was the seismic site characterization which consists of the determination of the ground-motion and shear-wave velocity of the indicated sites, aimed at having a general view of the variation indicate sites, aimed at having of soil conditions.

Damage caused by earthquakes suggest that these effects are the direct result of local geological conditions affecting ground motion. The best approach to understanding ground conditions is through direct observation of the seismic ground motion, but such studies are restricted to areas with relatively high seismicity.

On the basis of this approach, the team at CNR and the team of Prof. Duni have decided to integrate knowledge of the subsoil structure of heritage sites with geophysical surveys.

The geophysical surveys were carried out from November 2011 until December 2011.

The geophysical method applied for in-situ site exploration were:

- Seismic ambient noise
- MASW (Multichannel Analysis of Surface Waves)

The next pages explains the method of investigation and analysis methodology.

Table 5 indicates the location of the seismic ambient noise. The coordinates are in UTM 34 WGS84.

In Figs. 14, 15, 16 and 17 the ortophotos of the sites of MASW and ambient noise measurements in Apollonia, Berat, Butrint and Gjirokastra are presented (ANNEX II).

Table 5. Location of seismic ambient noise, measurement performed in Apollonia, Berat, Butrint and Gjirokastra.

Measurement	Site	Latitude	Longitude
AL01	BERAT	411016.288	4506932.825
AL02	BERAT	411029.517	4506334.072
AL03	BERAT	411923.810	4506153.890
AL04	APOLLONIA	371032.507	4508887.417
AL05	APOLLONIA	371235.033	4509220.342
AL06	APOLLONIA	370257.067	4508967.873
AL07	BUTRINT	416341.964	4399876.373
AL08	BUTRINT	416219.859	4399954.690
AL09	BUTRINT	416187.249	4400063.368
AL10	BUTRINT	416216.676	4400083.164
AL11	BUTRINT	416166.413	4399554.375
AL12	GJIROKASTRA	427567.331	4437236.408
AL13	GJIROKASTRA	426865.695	4436378.932
AL14	GJIROKASTRA	426932.910	4436421.021
AL15	GJIROKASTRA	425935.259	4436331.942
AL16	GJIROKASTRA	426659.022	4437183.558
AL17	GJIROKASTRA	426054.705	4437372.140
AL18	GJIROKASTRA	427515.883	4435526.019
AL19	BERAT	411146.258	4507334.878

SEISMIC AMBIENT NOISE

Seismic tremor, or seismic ambient noise, is present everywhere on the Earth surface and is generated by atmospheric phenomena (ocean waves, wind), anthropic activity, and, obviously, Earth dynamics. It is also called microtremor because it involves very small oscillations (10^{-15}

Fig. 14. Location of MASW and ambient noise measurements in Apollonia.

Fig. 15. Location of MASW and ambient noise measurements in Berat.

Fig. 16. Location of MASW and ambient noise measurements in Butrint.

Fig. 17. Location of MASW and ambient noise measurements in Gjirokastra.

m/s^2 in acceleration), much smaller than those induced by earthquakes of any size in the near field. The geophysical methods based on tremor are called passive because they do not require any signal generated ad hoc, as, for example, the explosions used in the seismic prospection (Fig. 18).

Since the first empirical studies of Kanai (1957), a variety of methods have been proposed to retrieve information about the subsoil from tremor spectra recorded at a single station. Among them, the most popular is by far the HVSR technique, which consists of studying the ratio between the spectral and horizontal components of motion, and was first applied by Nogoshi and Igarashi (1970). The method was relaunched and divulgated by Nakamura (1989) as a fast tool to measure the local seismic amplification. Consensus has not been reached on this point, although it is widely recognized that HVSR is capable of providing a reliable estimate of the main resonance frequencies of subsoil, which is nevertheless a crucial information for the seismic engineer. Given the acknowledged capability of this technique to provide correct estimates of resonance frequencies, and given the fact that, if estimates of elastic wave velocities are available, these can be translated into lengths, it seems that the HVSR technique can also act as a stratigraphic tool.

The method has proven to be useful to estimate the fundamental period of soil deposits and constrain the geological and geotechnical models used for numerical computations, especially when there is a large impedance contrast with the underlying bedrock. However, it should be pointed out that the H/V technique alone is not sufficient to characterize the complexity of site effects and, in particular, absolute values of seismic amplification.

The data analysis procedure generally consists of the following steps:

1. the acquired signal is divided into windows of length L (in this work usually 30 minutes);
2. each window is detrended, tapered and padded with zeros;
3. the Fast Fourier Transform (FFT) is then computed for each window, as well as the amplitude spectrum (Fourier Spectrum);
4. the spectra of each window is smoothed;
5. the horizontal to vertical spectral ratio is computed at each frequency for each window;
6. the final HVSR function at each frequency is given by the average of the HVSR of each window; generally the HVSR is computed by averaging the horizontal spectra with the quadratic average and dividing it by the vertical spectrum.

The frequency corresponding to HVSR peak identifies the resonance frequency of soil deposit.

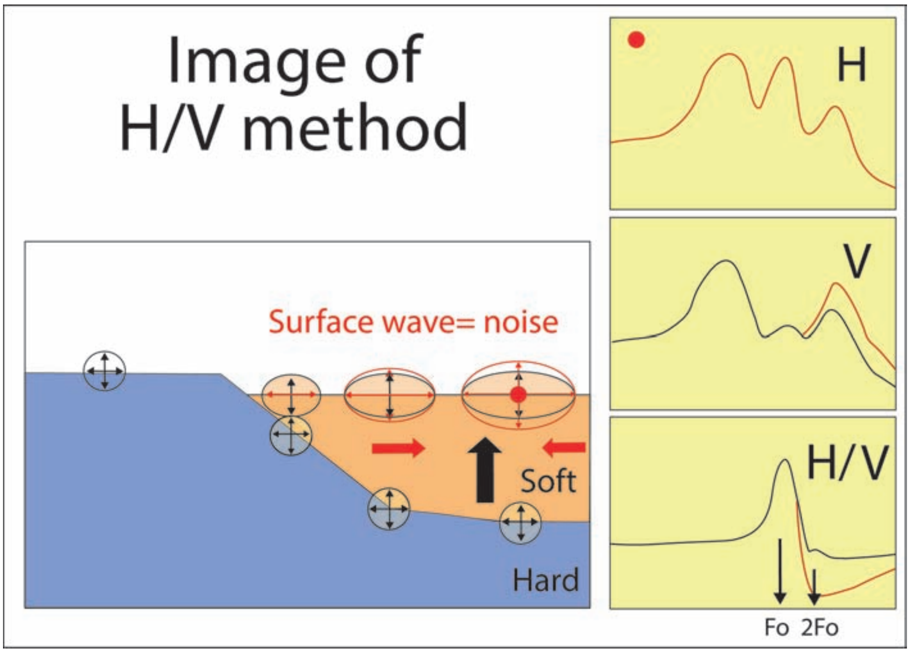

Fig. 18. Scheme of the H/V method.

MASW
MULTI-CHANNEL ANALYSIS
OF SURFACE-WAVES

Soil stiffness is one of the critical material parameters considered during an early stage of most geotechnical construction. Traditionally, several geotechnical or geophysical methods have been used to quantify soil stiffness. These include the cone penetration test (CPT) and down-hole seismic methods. CPT is an in-situ method that evaluates stiffness by measuring resistance to the penetration of a probe. Down-hole seismic method measures travel times to establish seismic velocities that are linked to stiffness. Among all other elastic parameters of materials, shear-wave velocity is the best indicator of stiffness. CPT and down-hole methods require the drilling of holes for probe penetration and give stiffness information that is representative of a localized volume near the hole. Shear-wave down-hole methods are generally considered less reliable because of difficulties in generating pure shear waves and processing the acquired data.

Multi-channel analysis of surfac- waves (MASW)

The surface-wave methods have recently become the seismic techniques frequently used to estimate the shear-wave velocity structure of soil because of their non-invasive nature and greater efficiency in data acquisition as well as processing. Propagation velocity of surface wave is frequency-dependent. This property is called dispersion. The heterogeneity in soils is mainly determined mainly by the vertical variation of shear-wave velocity. The heterogeneous properties of soils can be measured by recording the fundamental mode Rayleigh waves propagating horizontally. The fundamental-mode is usually represented by a curve depicting the variation of phase velocities with frequency. This curve is then used to estimate the vertical variation of Vs (shear-wave) through a process called inversion.

The multi-channel analysis of surface waves (MASW) utilizes pattern-recognition techniques made possible by multi-channel recording and processing approaches. The test employs multiple geophones equally spaced

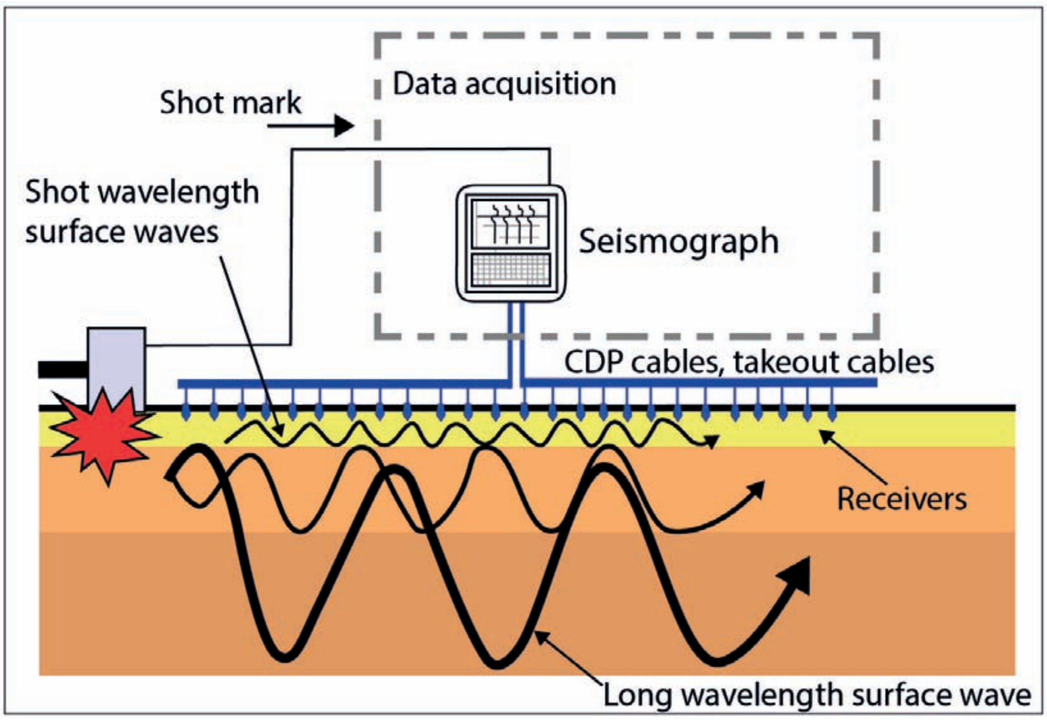

Fig. 19. Schematic diagram of MASW data acquisition.

along a linear survey line with seismic waves generated by an impulsive sources (Fig. 19). The surface waves are propagated along the receiver line where they are recorded synchronously. SeisImagerSW cross-correlates every pair of traces in a shot record, gathers all correlation traces by CMP, then those traces having equal spacing are stacked in the time domain. These additional steps improve the original MASW technique by effectively increasing the lateral resolution and accuracy of the final Vs cross-section. This approach allows recognition of the various propagation characteristics of the seismic wave-field. The main aspect of the seismic wave-field is the frequency dependency of phase velocities for all horizontally propagating seismic waves. The dispersive properties are imaged using a wave-field transform method. The dispersion characterized by Rayleigh waves are then identified in the image and a corresponding signal curve is extracted and used in the inversion process. A 1-D Vs profile is obtained from the inversion and this profile represents the best vertical Vs structure in the middle of the receiver spread used for the analysis.

Fig. 20. a,b,c) Images from the fieldworks in Apollonia; d, e, f) images from the fieldworks in Berat.

In contrast to the “active source” the “passive source” surveying, also called “microtremor array measurement” or “MAM”, does not consider time break and records the motion at various locations relative to the geophone spread that is obtained from ambient energy generated by cultural noise, wind etc. The fundamental assumption of microtremor data analysis using the spatial autocorrelation (SPAC) method of SeisImagerSW is that the signal wavefront is planar, stable, and isotropic (coming from all directions) making it independent of source locations.

In SeisImagerSW the results from “active” and “passive” source surveys can be combined to maximize the resolution and overall depth range of investigations.

The Fig. 20 are some pictures showing aspects of the fieldwork.

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3. LOCAL SEISMIC HAZARD ASSESSMENT: METHODOLOGY FOR SEISMIC MICROZONATION

The seismic microzonation studies are aimed at streamlining the knowledge of local seismic hazard, returning useful information for i) governance of the territory, ii) design of infrastructures, iii) planning for emergencies, and iv) reconstruction after the seismic event.

In planning - in particular - according to various scales and various levels of intervention, seismic microzonation studies are of fundamental importance for:

- guiding the choice of areas for new settlements;
- planning investigations and levels of detail;
- establishing guidelines and criteria of interventions in urban areas;
- establishing guidelines and criteria of interventions in cultural heritage sites;
- defining priorities for interventions.

In the design of new or retrofitting of existing infrastructures, seismic microzonation studies highlight the importance of phenomena such as possible amplification of shaking and permanent deformation triggered by the earthquake. Therefore, the seismic microzonation studies can provide relevant information useful for the design of infrastructures, with different effect, depending on the level of detail required by the relevance of the infrastructure itself.

The construction of a seismic microzonation study has different costs, depending on the level of detail. The utility of the study should be taken into consideration when deciding on the level of detail, in order to compare advantages to costs. The improvement of knowledge produced by seismic microzonation studies, together with studies of vulnerability and exposure, can concretely contribute to optimizing resources made available for mitigation of seismic risk.

The levels of analysis for studies of seismic microzonation, with increasing complexity and effort going from level 1 to level 3 ((Moscatelli et al., 2013), is follows (Fig. 21):

- level 1 is an introductory level to quantitative seismic microzonation studies - since it consists of a collection and analysis of existing information - designed to divide the territory

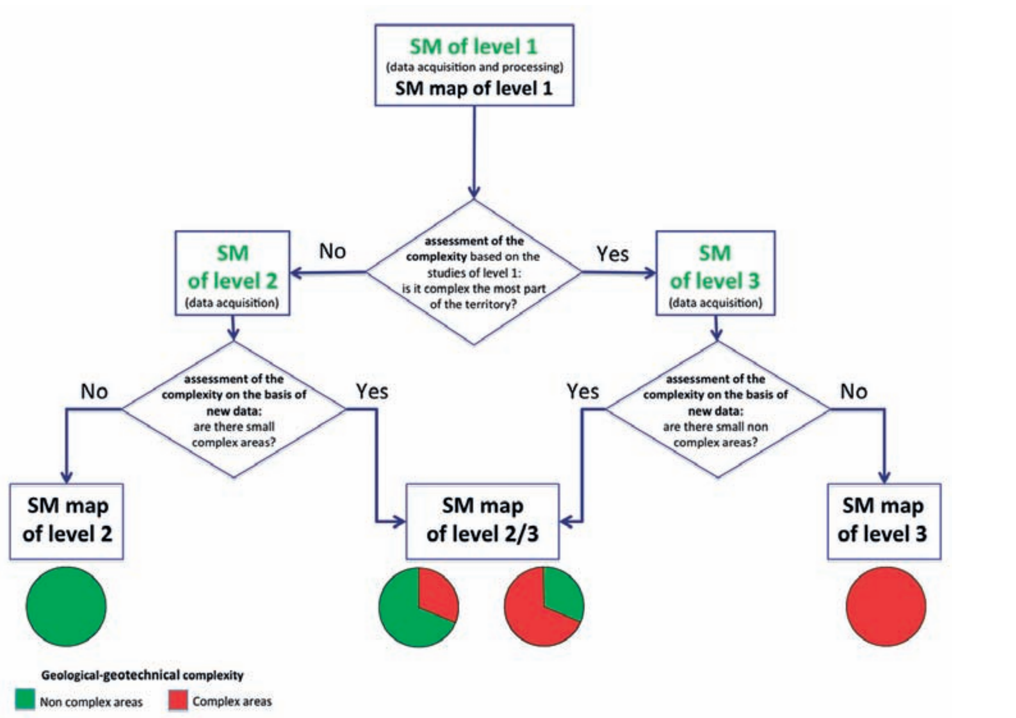

Fig. 21. Scheme of the seismic microzonation workflow in the Italian regulation (modified after Imprescia et al., 2013).

into seismic microzones qualitatively "homogeneous" in seismic perspective (Mancini et al., 2014);
- level 2 produces a quantitative map of seismic microzonation, by means of numerical simulations and pre-constituted abaci of relevant parameters;
- level 3 produces a quantitative map of seismic microzonation (Pagliaroli et al., 2013), by means of numerical simulations and new, targeted investigations, with emphasis on particular issues or critical areas.

The technical details of implementation and application of seismic microzonation proposed in this report are defined by the "Addresses and Criteria for Seismic Microzonation" (i.e., Indirizzi e Criteri per la Microzonazione Sismica) approved by the Italian Civil Protection Department (DPC) along with the Conference of Regions and Autonomous Provinces (Working Group, 2008).

The seismic microzonation map of level 1 identifies the geometry of microzones potentially characterized by specific seismic effects. This map, in particular, defines the microzones where ore likely the occurrence of different types of seismic effects such as local amplifications, slope instability, differential settlement, liquefaction, on the basis of geological and geomorphological observations and assessment of available lithostratigraphic data (Fig. 22).

In addition to the topographic maps, the suitable information for construction of a seismic microzonation map of level 1 comes from:
- geological and geomorphological maps;
- lithostratigraphic logs derived from drillings;
- geological and lithological cross-sections constructed with data derived from a) and b);
- hydrogeological maps.

The microzones of the map are classified into three categories:
- stable zones, where significant local effects of any nature are unlikely because the geological bedrock crops out in level or slightly sloping (less than 15°) areas.
- stable zones susceptible to local amplifications, where intensifications of ground motion are likely because of lithostratigraphic setting and local morphology;
- zones susceptible to geological instability (i.e., slope instability, differential settlement, liquefaction), in which the predominant and expected seismic effects are due to permanent deformations (amplification of ground motion is also possible).

In this report the seismic microzonations of level 1 of Gjirokastra, Berat, Butrint, and Apollonia are presented. Results of new geophysical surveys and seismic microzonation

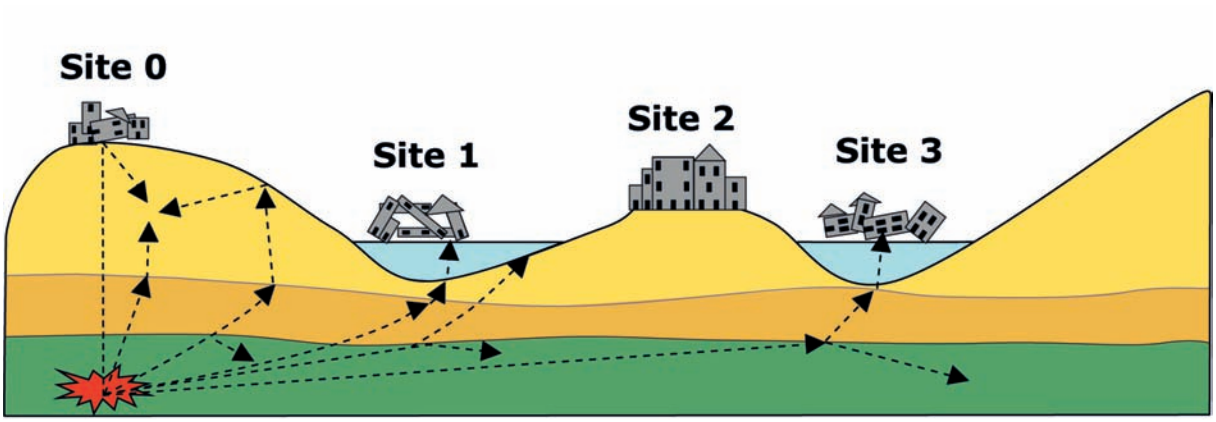

Fig. 22. Scheme of the earthquake waves propagation from the source with the possible seismic effects.

maps of the study areas are available in the Annexes.

It is noteworthy that no subsoil information from boreholes are available for any studied CH site. Because lithostratigraphic data are essential for a proper evaluation of site-effects, the proposed seismic microzonation maps could be improved when new subsurface information is made available. For this reason, new prospection campaigns are suggested for each case study.

The measurements comprise both the "active" and "passive" methods, enabling the characterization of a deeper velocity structure of more than 30 m.

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4. SEISMIC MICROZONATION OF APOLLONIA

GENERAL DATA OF THE SITE

Apollonia of Illyria is one of the most important Greek colonies in the lands of Illyria (Prendi. et al., 1965). The city is called Apollonia in honour of Apollo, sun god and protector of settlers. Based on written sources Apollonia was founded at the beginning of the six century B.C. (Amore, by colonists from Corinth and Corcyra). According to archaeological finds, the foundation of the city goes back to the end of seventh century B.C. (Fouilles archéologiques, 1987; Koço, 1987; Dimo, 1992; Amore, 2010). Apollonia was located on the first hill, which rises from the Myzeqeja plain approximately 10 km from the Adriatic Sea (Fig. 23), very close to the distance given by Strabo, who wrote that Apollonia is sixty stadia from the sea. Ten stadia from the City of Apollonia in antiquity through Myzeqeja plain or Gylachion Pedion. The navigable Aos River flowed very good connection to the sea. Strabo, says the foundation date of Apollonia 588 B.C., Stephanus of Byzantium, called it Apollonia of Illyria and said that the Corinthian settlers founded the local Taulanti tribe and stabilized first an emporium. He adds that the number of colonists was 200, first led by the colonizer Gylax (Prendi et al., 1965).

The geographical position favours trading with Greece, southern Italy and Illyrian cities too, Apollonia also developed as an important artisan centre. The city became a very important economical, political and cultural centre. Throughout history Apollonia is mentioned by ancient authors as allies in different conflicts, on of them being the civil war in 48 B.C., when the city opened its gates to Caesar. In 44 B.C. the future emperor Octavian and his friend Agrippa spent several months in Apollonia studying rhetoric [(Prendi et al., 1965; Pausanias, (Cezari, 37, 3), Cezari III, Valer Maksimi, (IX, 8, 2), Plutarku, Antonius, 16, Apiani, Historia Romana, 16; Plutarku, Brutos, 22, 2)]. Octavian gave the city the status of *"Civitas libera et imunis"*, free of taxes. Apollonia always remained a Greek culture city and used Greek language as well. Cicero called Apollonia *"magna urbs et gravis"*, but this big and important cite like Cicero called it, in the middle of the fourth and beginning of fifth century A.D. was abounded. A strong earthquake at 238 A.D. destroyed Apollonia, which was never rebuilt but declined and step-by-step was abounded. It seems that the Aos River, a very important connection between Apollonia and the sea, change its course after the earthquake, so the city lost its fluvial port, and with that lost commerce and importance, too (Fouache et al., 2001; Prendi, 1965). From Apollonia a lot of roads like Via Egnatia started crossing through Fier, Rroskovec, and also over the ancient river Apsus at the present Kuçova town, going northeast and crossing the Scampinus River (Fig. 24).

From this road Saint Paul arrived to the Illyrian lands and with him Christian religion. So after the earthquake what remained of Apollonia was an Episcopal centre.

Apollonia flourished during classic and Hellenistic time, becoming a very big city, about 120 hectare inside city wall, surrounded by a 4.5-km long perimeter walls fortified with many towers protecting the gates of the city (Blavatski, 1958; Ceka, 1963; Dimo, 1984; Koço, 1988).

The fortification wall is one of biggest monuments in Apollonia (Fig. 25a). It was built in different phases, starting from the archaic and classic periods, also in the Hellenistic and Roman period. The last intervention was documented in Justinian times. However, in this period, it was just religious centre (Ceka, 1982; Ceka, 2005).

Built on the hill was needed and planning very good organization. For that reason they had to build terracing walls into the city. The terracing walls are a testimony of a lot of work remodelling the natural view. The urban plan is

Fig. 23. Location from the archaeological map of Apollonia.

very clear, with straight streets crossing each other and creating squares, also dividing public and private areas (Mano and Dauta, 1982; Dimo, 2007; Fiedler and Franz, 2011). In the public area, monumental buildings like temples and administrative contractions were concentrated. It seems that firstly the city started to the built on one of the highest parts of the hill known as the acropolis, located in the northern part of city, and step by step extended all over the hill (Figs. 25b, 26). One of the most important areas is the temenos (sacred area), surround by a decorated terracing wall of the third century B.C. It is the dominant point of Apollonia, 104 m above sea level, where the temple of Apollo is. Agora was built in between these two hills during classic period and in the south of temenos in Hellenistic and Roman times. From the numerous excavated monuments it is possible to see that everything is carefully calculated. Is interesting the reorganization during the Roman Imperial period. During these times many buildings were built over earlier classical period ruins.

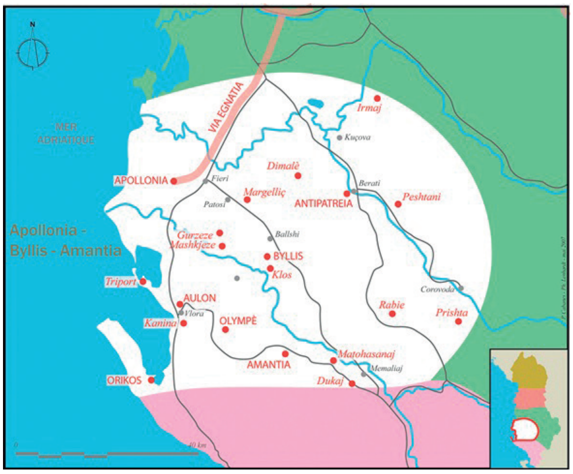

Fig. 24. Via Egnatia (Carte Archeologique de l'Albanie).

The *bouleterion* date second century A.D., 11 m high monument is reconstructed in 1976-77 (Fig. 25c). Corinthian-style columns were built in marble imported from Italy (Carrara). A greek language inscription on the architrave calls this monument *Agonothetas*, which describes of two brothers holding the position of the *agonothetas.* The inscription says that twenty-five gladiators pairs fought in the inauguration day, which is a very clear Roman style. Odeon is a small covered theatre and could fit no more than 300 people in it, and it lies in front in the northern side of *bouleterion*, in the second century A.D. It was built in the same *opus testaceum* style. Date from the second century A.D., it is a square building and lies over the ruins of classic period *stoa*. The library was built in the same building technique with

Fig. 25. Archaeological Area of Apollonia: a) Southeast portion of the fortification wall; b) relay ramp to the acropolis; c) Bouleterion temple; d) monastery and church of the Saint Mary.

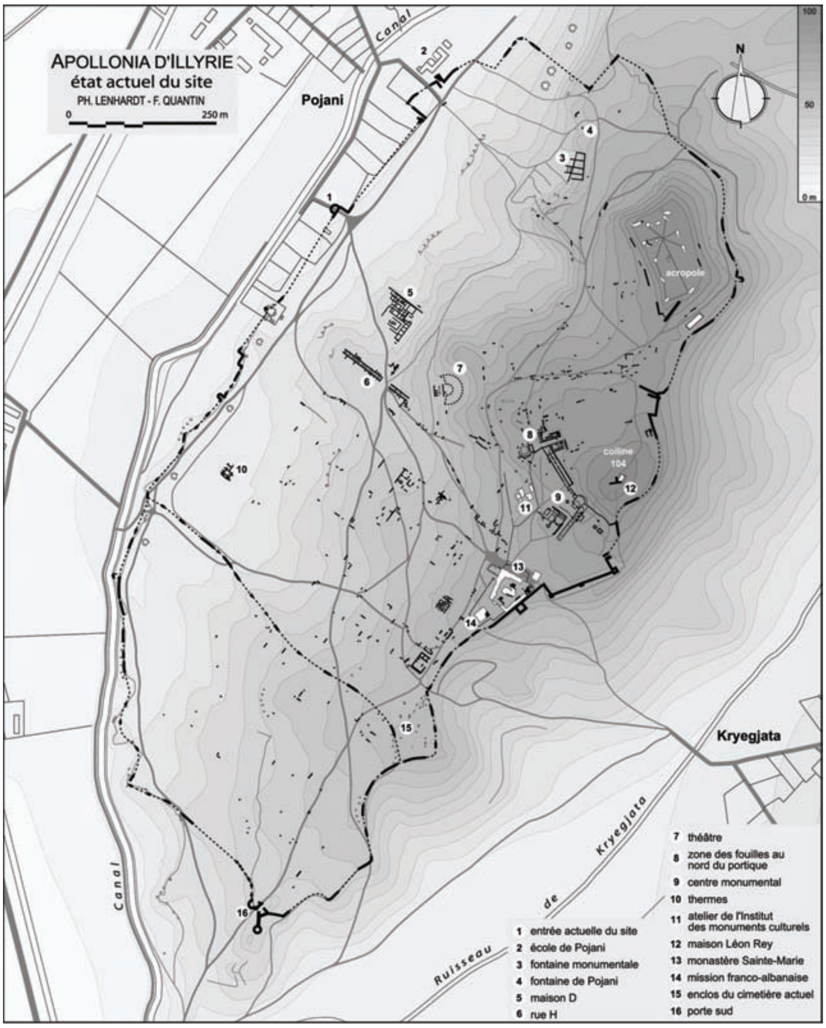

Fig. 26. View of Apollonia (Atlas Archeologique et Historique, from Dimo et al., 2007).

Roman cement and *opus testaceum*, like the *prytaneion*, triumphal arch, and the Roman temple, all part of the monumental center of the *agora* of Apollonian. *Stoa* B, 72 m long and 14 m wide, dates to the middle of the fourth century B.C., and is one of the most interesting monuments in the agora of Apollonia. The wall with seventeen niches was used as a terracing wall, and the half-dome shape of the upper part of the niches was used to hold the weight of the first floor. During the excavation marble statues were found in some niches. A row with Doric style octagonal colons divides the *stoa* into two walkways.

The *nymphaeum* date to the fourth century B.C. Five stepping channels brought the water down to the Doric colonnaded main chamber. It is one of the most important and beautiful monumental buildings in Apollonia. It lies on the original slope of the hill north of the city.

Private houses were built in a very good rectangular system, many of them paved with mosaic floors especially the Roman time houses. The most interesting houses with mosaic floors probably belonged to aristocracy. One of them has a *impluvium*, and another one which is called *Atenes* house has a peristyle and a fountain in the center. All the houses excavated until now have a water cistern or a well inside the courtyard.

The Middle ages are represented by the monastery and church of Saint Mary standing onto the remains of Christian buildings (Fig. 25d). This complex was built in the 13^{th} century. Byzantine style was mixed with south Italic art. Today has been adopted by the archaeological museum, where there a very interesting exhibition with artefacts from prehistory to the Roman period. Today, like in ancient periods, the site is exposed to different risks. Two strong earthquakes documented in 238 and 345 B.C. are the main reasons Apollonia was abandoned. That means that the houses, monumental buildings and also terracing walls collapse and were never reconstructed. A big loss for the city was was the inability of navigation in the river as a result of the displacement of the coastline to the west, related with the geological processes. There is not much evidences of restoring. In some of them, however, there was some ancient restoration. One of them was the perimeter wall in the eastern part, and the central wall, which cut off about 30 ha from southern part of the city. Some damages of the seating area of the theater maybe are connected to landslides, a phenomenon present even now days (Fig. 27a) . From the observations land sliding is present in the east part of the hill, but in this area the descending is slow. (Fig. 27 b,c).

Fig. 27. Archaeological Area of Apollonia: a) theater, effect of lanslide fenomena along the western flank of the acropolis; b) collapse of the walls in the acropolis; c) fractures relate to the instability phenomena inside the monastery and church of the Saint Mary; d) Effect of gravity sliding on the eastern wall.

GEOLOGICAL OVERVIEW OF APOLLONIA AREA

The study area extends over the archaeological site of Apollonia, which is located on the last hills that flank the Albanian coastal plain, near the city of Fier.

From a regional perspective, Apollonia lays in the molasse basin covering the external part of the Albanides thrust-fold belt (Velaj et al., 1999), a mountain range developed as a result of subduction of a branch of the Tethys ocean (Vardar ocean) and collision of the Apulian promontory (African Plate) and the Balkans (Euroasian Plate). As such, Albanides represent a segment of the Dinar-Albanian-Hellenic Arch of the Alpine Orogen (Velaj et al., 1999), which can be further subdivided in an internal zone of ocean crust-derived units, Internal Albanides, and an external sector representing the southwest passive margin of the Vardar Ocean, External Albanides.

Internal Albanides are represented by a pile of thrust sheets incorporating Jurassic ophiolites unconformably covered by Cretaceous shallow-water clastic and carbonate sediments (Collaku et al., 1990, 1992; Kodra et al., 1993a,b; Dorre and Malo, 2010), which are overthrusted toward the southwest onto the External Albanides.

In turn, External Albanides constitute the southwest passive margin of the Vardar ocean, which consisted of two platform domains, Sazani and Kruja, separated by the Ionian basin hosting the deposition of thick shelfal to basinal

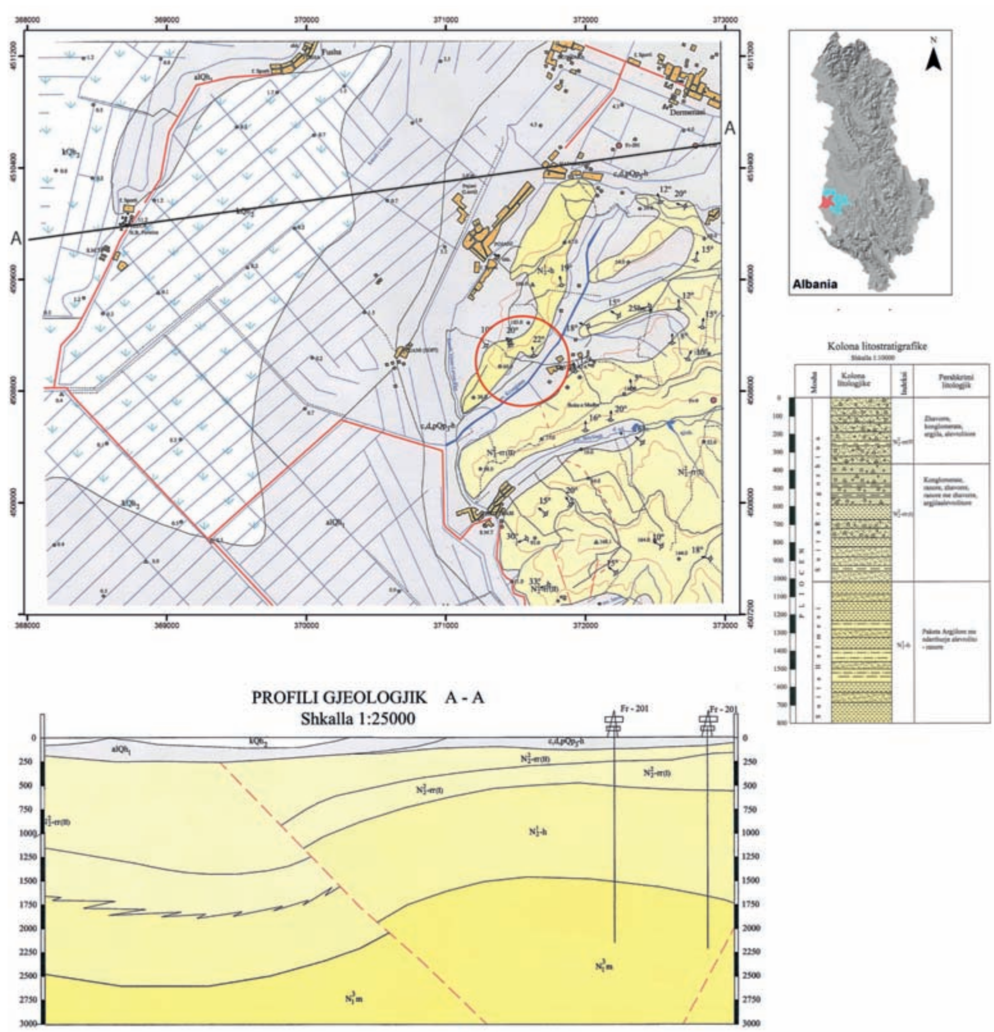

Fig. 28. Geological map and cross-section of the Apollonia area. (from Dorre and Malo, 2010, modified).

Mesozoic–Cenozoic sedimentary successions. In this paleogeographic setting, the Sarzani domain represents the autochthonous peripheral part of the Apulia platform, whilst the Ionian and Kruja domains constitute allochthonous units overthrusted westwards onto the Apulian foreland.

In External Albanides, tectonic deformation occurred in a foreland-forward thrusting sequence with trends rotating from NNW-SSE to NW-SE along three main phases, the first involving the Kruja domain (Eocene), the second (late Oligocene-Miocene) mainly involving the Ionian basinal sediments, and the third (Pliocene) involving the Ionian and the Apulian platform. In the latter phase the Apulian platform acted as a rigid buttress promoting out-of sequence thrusting of more internal units (Roure et al., 1995).

In terms of structural style, External Albanides thrust-fold belt is constituted by two main supra-salt tectonic units (Ionian and Kruja units) made of tick piles of Jurassic to Eocene shelf and slope-to-basin limestones, which are overthrusted over the Apulian foreland (Sarzani domain) by means of sole thrust located along Upper Triassic evaporites. In this structural edifice can be recognized both imbricate and duplex styles whilst triplex style is more rarely observed.

The molasse basin develops mainly in front of the Kruja units and unconformably covers the Ionian structures. In the Apollonia area, in particular, the hill hosting the archaeological site is constituted by alternating marine clays, sands, and conglomerates Pliocene in age (Fig. 28), with a coarsening and shallowing-upward trend recorded by the sedimentary succession. The Pliocene succession is deformed with a broad anticline associated with a reverse fault verging towards the west (Fig. 28).

The Pliocene sedimentary units are in turn unconformably covered by Quaternary continental deposits, that constitute the coastal plain located in front of the Apollonia ridge (Fig. 28).

SEISMIC HAZARD OF APOLLONIA CULTURAL HERITAGE SITE

In Fig. 29 there is a fragment of the map of active faults in Albania for the Apollonia area (Aliaj et al., 2004) with the main earthquakes that have occurred in this area. The active structural elements are represented on this map by the type of deformation (normal fault, reverse fault, thrust and backthrust, strike-slip, flexure, evaporite diapir dome) and their chronology of activity. They are distinguished by colors.

Hazard curves

The relationship between the ground-motion level and its annual probability of occurrence is described by a hazard curve. In Fig. 30 there are the hazard curves we developed for PGA and response spectral accelerations for a suite of periods with engineering interest of Apollonia cultural heritage sites. Then, the annual frequency of exceedances are plotted (dashed horizontal lines), which correspond to probabilities typically used for the design, like 10% in 10 years (RP = 95 years), and respectively 10% (RP = 475 years), 5% (RP = 975 years), 2% (RP = 2475 years) and 1% (RP = 5000 years) in 50 years.

Uniform Hazard Response Spectrum (UHRS)

The decision to use response spectral values was based on earthquake data obtained during the past 20-plus years showing that site-specific spectral values are more appropriate for design input than the coefficients based on peak ground acceleration used with standard spectral shapes. The differences are particularly pronounced in the short-period portion of the response spectra (Leyendecker et al., 2004).

In this study we considered five hazard levels: 10% of exceedance probability in 10 years, and 10%, 5%, 2% and 1%, respectively, in 50 years, corresponding to years = 95, years = 475, years = 975, years = 2475 and 5000 years-return periods, respectively. The maximum horizontal

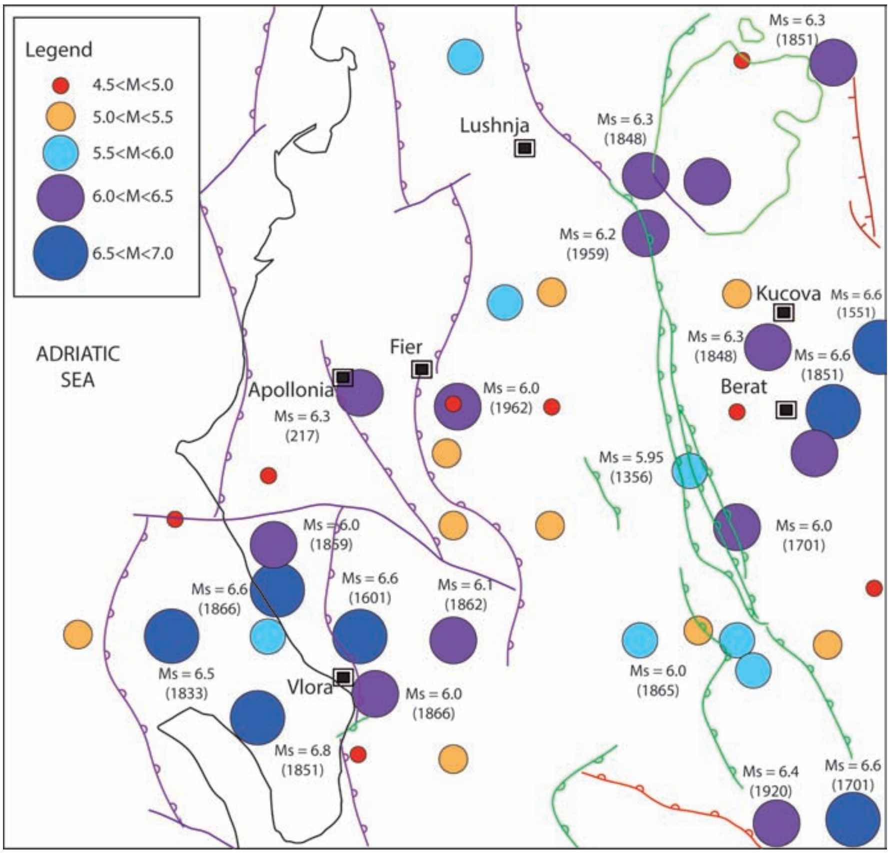

Fig. 29. Active faults in the Apollonia site area and its vicinity (from Aliaj et al., 2004). The colors express the chronology of fault activity, noted as follows: blue-Quaternary, green- Pliocene-Quaternary, and red–pre-Pliocene, but active also during Pliocene-Quaternary. The epicenters of the earthquakes around Apollonia are also noted.

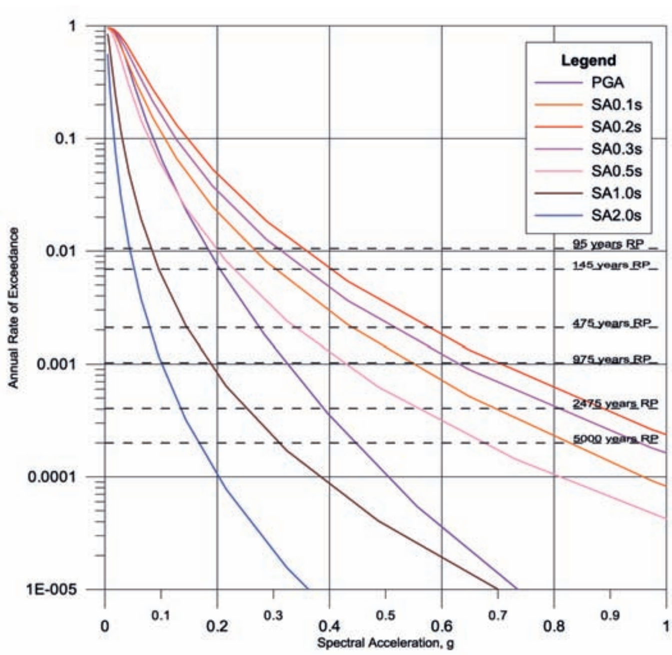

Fig. 30. Seismic hazard curves (rock conditions) for PGA and spectral accelerations SA 10 Hz, 5 Hz, 3.3 Hz, 2 Hz, 1 Hz and 0.5 Hz for Apollonia Cultural Heritage site.

bedrock PGA and spectral accelerations (SA) for each RP were obtained from PSHA and are listed in Table 6. The uniform hazard spectra (UHRS) for each RP for Apollonia cultural heritage sites are plotted in Fig. 31.

Table 6. Maximum horizontal bedrock PGA and SA for Apollonia Cultural Heritage site.

Period	Spectral Acceleration, g				
Sec	RP=95y	RP=475y	RP=975y	RP=2475y	RP=5000y
PGA	0.182	0.274	0.320	0.389	0.442
0.10	0.261	0.439	0.537	0.688	0.812
0.20	0.347	0.569	0.693	0.875	1.031
0.30	0.306	0.506	0.624	0.794	0.949
0.50	0.197	0.337	0.420	0.550	0.667
1.00	0.081	0.146	0.185	0.248	0.309
2.00	0.044	0.078	0.100	0.134	0.165

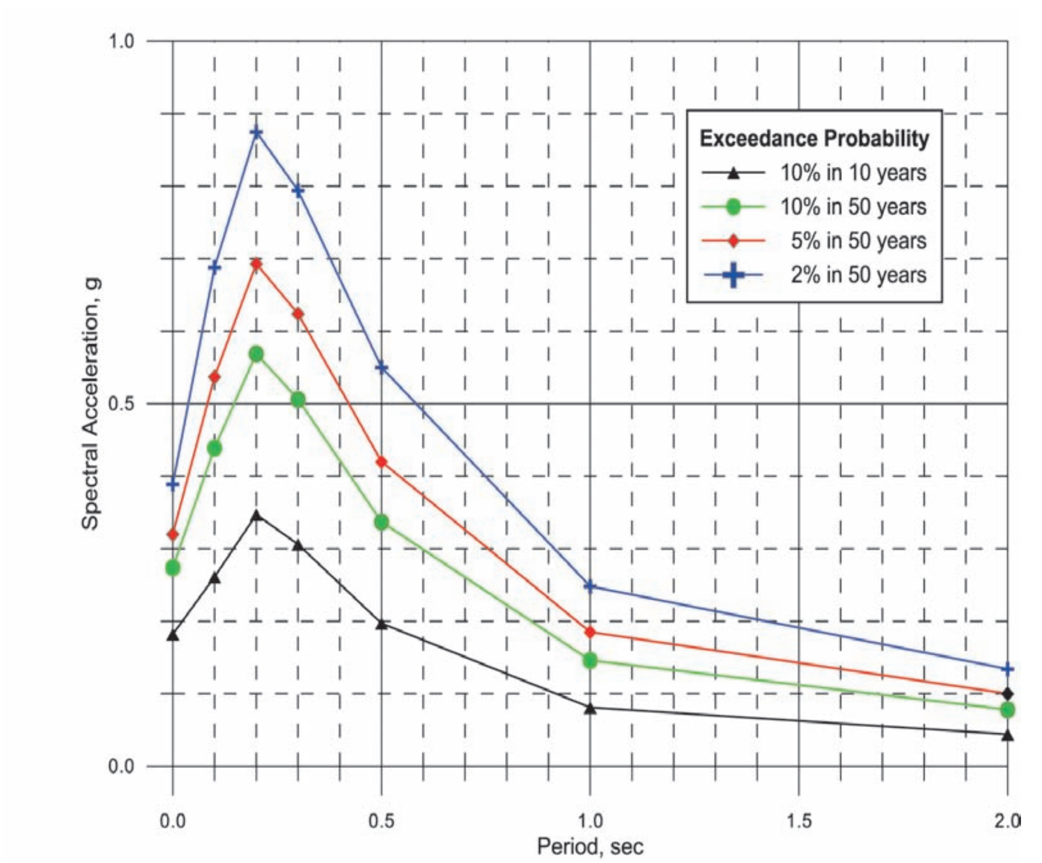

Fig. 31. Uniform hazard spectra for 1%, 2%, 5% and 10% probability of exceedance in 50 years, and 10% probability of exceedance in 10 years for Apollonia Cultural Heritage site.

SEISMIC MICROZONATION OF LEVEL 1 IN APOLLONIA

The seismic microzonation map of level 1 of Apollonia has been carried out (Annex III) in the light of i) results of new geological surveys, ii) new MASW prospections, and iii) new measurements of ambient noise (Fig. 14).

Data analysis has allowed establishing the presence of both stable zones susceptible to local amplifications and zones susceptible to geological instability. Zones are numbered in ascending order, based on the amplification expected.

Stable zones susceptible to local amplification

Zone 1) Geological bedrock

This zone occupies the hill hosting the core of the archaeological area of Apollonia. The subsoil of the hill is a geological bedrock characterized by alternations of both loose and cemented terrigenous deposits Pliocene in age, with monoclinal arrangement and dipping about 20° towards NNE. The eastern portion of the hill is characterized by the presence of both loose deposits (silt and sand) and cemented deposits (sandstones and conglomerates), which pass towards NNE to alternating ochre silt, sand, and pebbly sand. The scarcity of outcrops, the lack of drilling and the impossibility of carrying out a detailed geological survey make it impossible to properly define the partial thicknesses of the succession. In any case, the information obtained from a MASW performed close to the monastery (L04, Annex II) confirms the presence of a layer with Vs values up to 500 m/s just below the first 5-10 meters of colluvial-eluvial recent covers. The MASW made at the top of the hill-in agreement with the results of noise measurements (L05, Annex II) - highlights, however, the presence of a layer with Vs values less than 300 m/s at depths between 5 and 15 meters from the ground surface, covering a layer with increasing Vs values up to 500 m/s. The lithological differences, underpinned by the Vs values, allow for the identification of two sub-areas, the first on the eastern flank of the hill which less susceptible to seismic amplification, and the second on the western flank of the hill which more susceptible to seismic amplification.

Zone 2) Colluvial-eluvial covers

This zone has a limited extension and occupies the valley bordering the east side of the hill of Apollonia. Taking into account the geological and geomorphological settings, colluvial-eluvial deposits of Quaternary age - with a maximum thickness of 10-15 meters- should cover the geological bedrock here, which is characterized by alternations of loose silt, sand, and pebbly sand.

Zone 3) Coastal plain

This zone extends west of the hill of Apollonia and is characterized by the presence of sandy-silty loose Quaternary deposits, which unconformably cover silt, sand and pebbly sand of the geological bedrock. The maximum thickness expected in the study area does not exceed 20 meters. (Annex III).

Zones susceptible to geological instability

Zone 4) Zone susceptible to gravitational instability

The western sector of the hill of Apollonia shows several gravitational instabilities of limited extension (mainly earth flows and solifluctions) affecting the sandy-silty bedrock next to monuments, archaeological excavation and man-made terraces. It is noteworthy that these phenomena should be monitored regardless of their susceptibility under seismic conditions, because their origin is probably due to 1) not appropriate excavations carried out on the hillside and 2) by a lack of regimentation of surface water, (Annex III).

Suggestions for further study

The seismic microzonation level 1 presented in this report enables us to divide the territory of Apollonia into two main zones: the hilly area, less susceptible to seismic amplification and the coastal plain, more susceptible to seismic amplification, given the presence of very soft Quaternary sediments. The main uncertainties related to the subdivision of this territory in zones with different susceptibility to seismic amplification are related to 1) not well-known distribution of lithotypes characterizing the geological bedrock and 2) not well-known thickness of the Quaternary cover in the lateral valleys and coastal plains (Annex III). For this reason is desirable that these uncertainties are reduced through i) a detailed geological-geotechnical survey of the archaeological area and ii) the use of geophysical methods, which provide information on the thicknesses of the recent soft covers.

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5. SEISMIC MICROZONATION OF BERAT

GENERAL DATA OF THE SITE

Berat is located on a hill, around 200 m above sea level, at the foot of Mt. Tomorr, overlooking the valley of the Osum River. Berat is a fortified and open city, once populated by craftsmen and merchants (Fig. 32).

The castle of Berat was listed as a national cultural monument in 1948. Individual buildings of architectural ensembles within the city were listed also but separately.

The the city of Berat was inscribed in combination with Gjirokastra in the World Heritage property under the apelate of Historic Centres of Berat and Gjirokastra in 2008. They were inscribed on the basis of criteria(iii) and (iv) as per Decisions 29 COM 8B.48 and 32 COM 8B.56.

Criterion (iii): Berat and Gjirokastra bear outstanding testimony to the diversity of urban societies in the Balkans, and to longstanding ways of life which have today almost vanished. The town planning and housing of Gjirokastra are those of a citadel town built by notable landowners whose interests were directly linked to those of the central power. Berat bears the imprint of a more independent life style, linked to its handicraft and merchant functions.

Criterion (iv): Together, the two towns of Gjirokastra and Berat bear outstanding testimony to various types of monument and vernacular urban housing during the Classical Ottoman period, in continuity with the various Medieval cultures which preceded it, and in a state of peaceful coexistence with a large Christian minority, particularly at Berat.

Located in central Albania, Berat bears witness to the coexistence of various religious and cultural communities through the centuries. It features a castle, locally known as the "Kala" most of which was built in the 13th century, although its origins date back to the 4th century B.C. The citadel area has many Byzantine churches, mainly from the 13th century, as well as several mosques built under

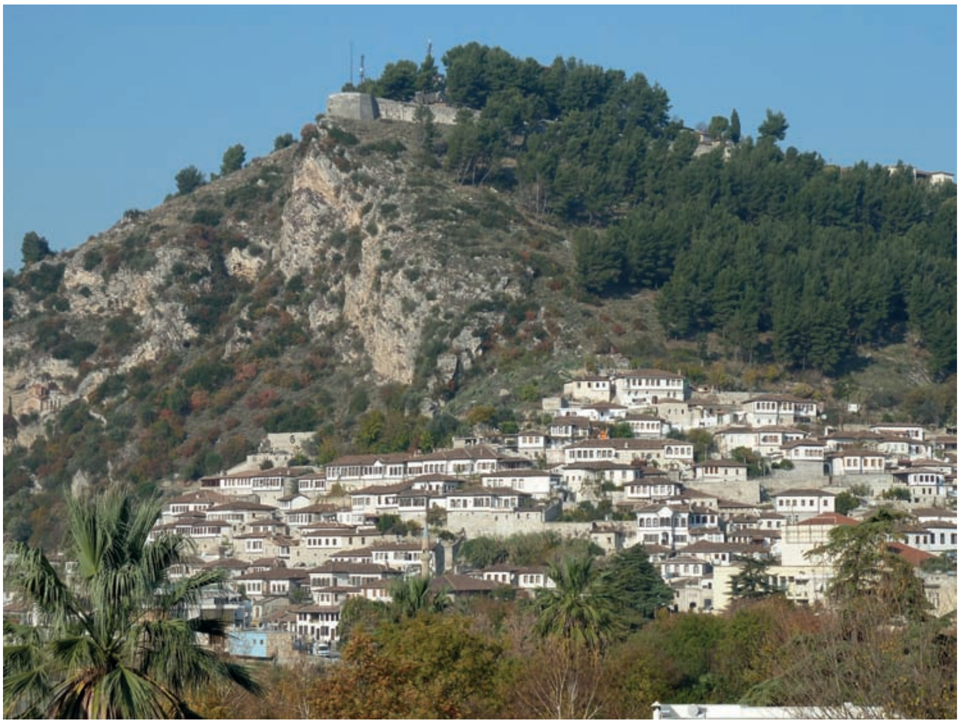

Fig. 32. View of the city of Berat and the castle.

the Ottoman period. The city comprises urban quarters dating back to the15th-19th century.

The settlement is traditionally believed to have been founded by Cassander, King of Macedonia, in 314 B.C. and later was placed under the Roman protectorate.

Excavations around the medieval city walls of Berat have resulted in the identification of parts of the first wall circuit, including the remains of a major gateway. These wall sections date back to the 4th century B.C. (Braka, 1990).

The finds from the excavations within Berat date back to the 7th century B.C., which suggests that the city of Antipatrea was possibly which suggests that the city maybe Antipatrea was established on an existing Illyrian settlement.

In 440 A.D. the city was renamed *Pulcheropolis* by Emperor Theodosius II (408-450 A.D.) after his sister. Later the city walls were rebuilt most probably during the reign of the Emperor Justinian (527-565 A.D.).

In the 9th century *Pulcheropolis* fell to the Bulgars. The city was renamed Belgrade (from which the modern name of Berat derives) and was the seat of a bishopric. The Bulgars lost the city in the 11th century to the Byzantine Empire. Under the Despotate, the Muzaka family dominated Berat.

The city was refortified in the 13th century. Its walls were rebuilt, following the contours of the hill, to form a triangular fortress enclosing 9.6 hectares (Fig. 33). The city walls were protected by a system of towers. Within the city, a castle was constructed on the summit of the hill. Alterations and additions were made to the system of fortifications throughout the following century, and included an extension of the fortified area by the construction of two defensive walls running from the south side of the city wall to the river. This extension enclosed a further six hectares. Several churches dating to the 13th and 14th centuries have survived within the city - the churches of St George, St Michael and the Holy Trinity being the best-preserved (Fig. 34).

In 1417 Berat fell under Ottoman control. The fortifications were maintained with the addition of urban quarters at Gorica and Mangalem, outside the medieval fortifications. The city prospered under the Ottomans, and much of the historic centre of modern Berat comprises Ottoman-period houses (fine 17th and 18th century stone-built dwellings) and, close to the river, timber-framed shops of the old bazaar. In addition there is an important group of mosques including the late 15th century Sultan's Mosque (*Xhamija e Mbretit*), the 16th century Leaded Mosque (*Xhamija e Plumbit*) and the 19th century Mosque of the Bachelors (*Xhamija e Beqareve*). A group of 18th century buildings associated with the Tekke of the Helvetis have also survived. Many churches were also constructed in this

Fig. 33. Aerial view of the Berat fortifications.

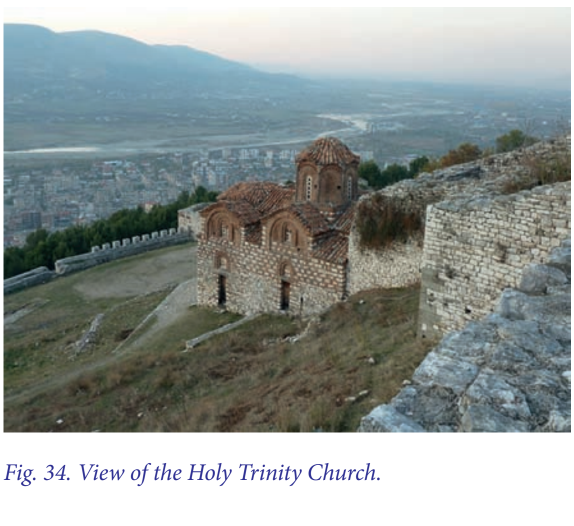

Fig. 34. View of the Holy Trinity Church.

period, decorated by Onufre, a 16th century Albanian painter, and his school of painters. A museum of Onufre's work can be found in Berat.

Problems and Risks

The development threat

Urban expansion and tourism development pose a specific threat to the cultural heritage of Albania including historic towns such as Berat. The local developments are the most serious threats even though some of the projects are State-led and internationally sponsored.

In order to protect and conserve the cultural assets of the city, the WHS is requiring periodic reporting to the World Heritage Centre. The institution responsible should fulfill the below listed requirements:

a) prepare a list of illegal buildings dating from the '90 until today, together with plans of destruction of these illegal constructions;
b) define the monitoring indicators together with the intervals of updates;
c) prepare proposals regarding the program of archaeological excavation in accordance to international standards;
d) improve protection against fire in the historic zone;
e) compile medium-term plan for development of capacity for tourist facilities.

GEOLOGICAL OVERVIEW OF BERAT AREA

The study area extends over the town of Berat, and straddling the Osumi River where it cuts through the Berat Anticline (Fig. 35).

From a regional perspective, the Berat area lays in the External Albanides (Velaj et al., 1999), whose tectonic deformation occurred in a foreland-forward thrusting sequence with trends rotating from NNW-SSE to NW-SE along three main phases; the first involving the Kruja domain (Eocene), the second (late

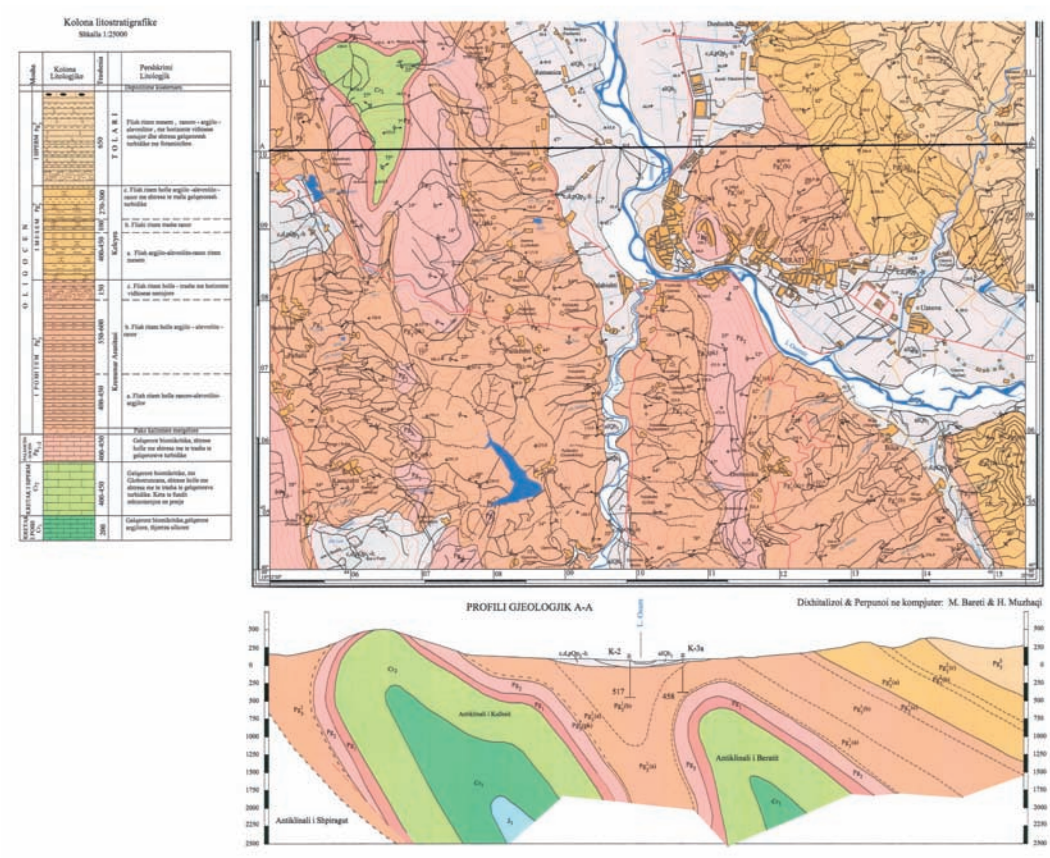

Fig. 35. Geological map and cross-section of Berat area. (from Velaj and Bakia, 2010).

Oligocene-Miocene) mainly involving the Ionian basinal sediments and the third (Pliocene) involving the Ionian and the Apulian platform.

The Berat belt (Fig. 35) is one of the three main anticlinal belts (Berat, Kurveleshi and Cika) of the Ionian domain and is characterized by a marked asymmetry due to westward overthrusting onto the more external Kurvaleshi belt. The Berat fold (Fig. 35) is represented by a N-S anticline which at surface gently peter out toward the N into a periclinal structure. The lithostratigraphic units constituting the Berat belt, apart from the Quaternary alluvial deposits covering the geological bedrock, mainly related to the Osumi River, are Cretaceous to Oligocene in age and include, from base to top: i) upper Cretaceous to Eocene limestones, with turbidite intercalations and marls; ii) Oligocene siliciclastic deposits.

SEISMIC HAZARD OF BERAT CULTURAL HERITAGE SITE

On Fig. 36 there is a fragment of the map of active faults in Albania for the Berat area (Aliaj et al., 2004) with the main earthquakes that have occurred in this area. The active structural elements are represented on this map by the type of deformation (normal fault, reverse fault, thrust and backthrust, strike-slip, flexure, evaporite diapir dome) and their chronology of activity. They are noted by color.

Hazard curves

In Fig. 37 presented are the hazard curves we developed for PGA and response spectral accelerations for a suite of periods with engineering interest, for Berat cultural heritage site. Then, the annual frequency of exceedances are plotted (dashed horizontal lines), which correspond to probabilities typically used for the design, like 10% in 10 years (RP = 95 years), and respectively 10% (RP = 475 years), 5% (RP = 975 years), 2% (RP = 2475 years) and 1% (RP = 5000 years) in 50 years.

Uniform Hazard Response Spectrum (UHRS)

For Berat we considered five hazard levels: 10% of exceedance probability in 10 years, and 10%, 5%, 2% and 1% respectively, in 50 years, corresponding to 95-years, 475-years, 975-years, 2475-years and 5000-years return periods, respectively (Table 7). The maximum horizontal bedrock PGA and spectral accelerations (SA) for each RP were obtained from PSHA and are listed in Table 4. The uniform hazard spectra (UHRS) for each RP for Berat cultural heritage sites, are plotted in Fig. 38.

SEISMIC MICROZONATION OF LEVEL 1 IN BERAT

The seismic microzonation map of level 1 of Berat (Annex IV) has been carried out in the light of i) already available information, ii) new MASW prospections and iii) new measurements of microtremors (Fig. 15).

Data analysis has allowed us to establish the presence of both stable zones susceptible to local amplifications and unstable zones susceptible to geological instability. Zones are numbered in ascending order, based on the amplification expected.

Stable zones susceptible to local amplification

Zone 1) Marly-calcareous geological bedrock

This zone occupies the historic center of the city, and is characterized by the presence of layered and fractured marly limestone. The structural setting of marly-calcareous bedrock generates an anticline with a sharp periclinal termination towards the north. Apart from the very top of the hill (into the castle), the rise is characterized by steep slopes (>15°), which can cause topographic amplification of seismic motion.

Shear velocity (i.e. Vs) values, measured via MASW technique (L02 in Annex II), confirm, shear wave velocities generally higher than 800

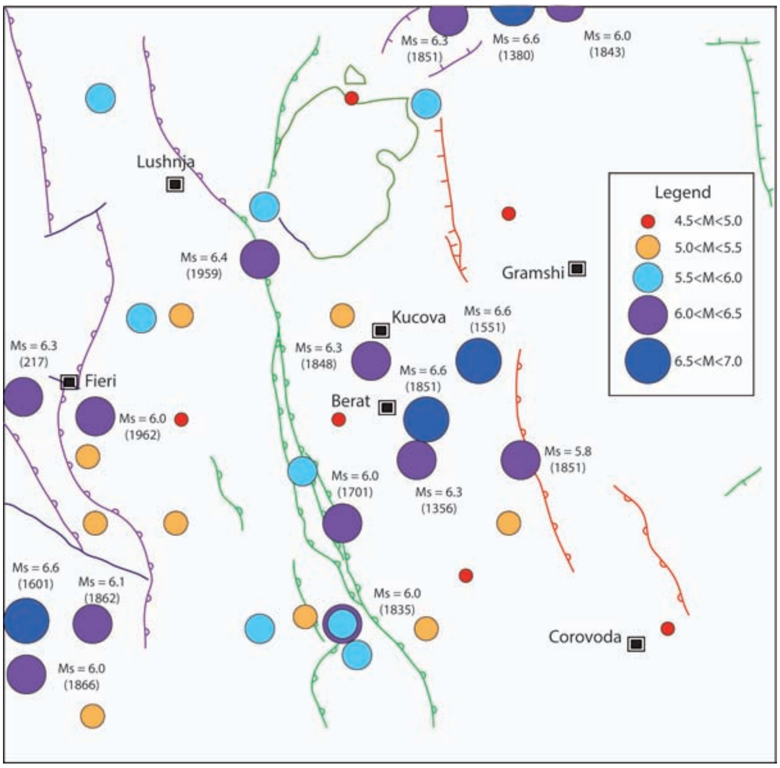

Fig. 36. Active faults in the Berat site area and its vicinity (from Aliaj et al., 2004). The colors express the chronology of fault activity, noted as follows: blue-Quaternary; green-Pliocene-Quaternary, and red-pre-Pliocene, but active also during Pliocene-Quaternary. The epicenters of the earthquakes around Berat are also noted.

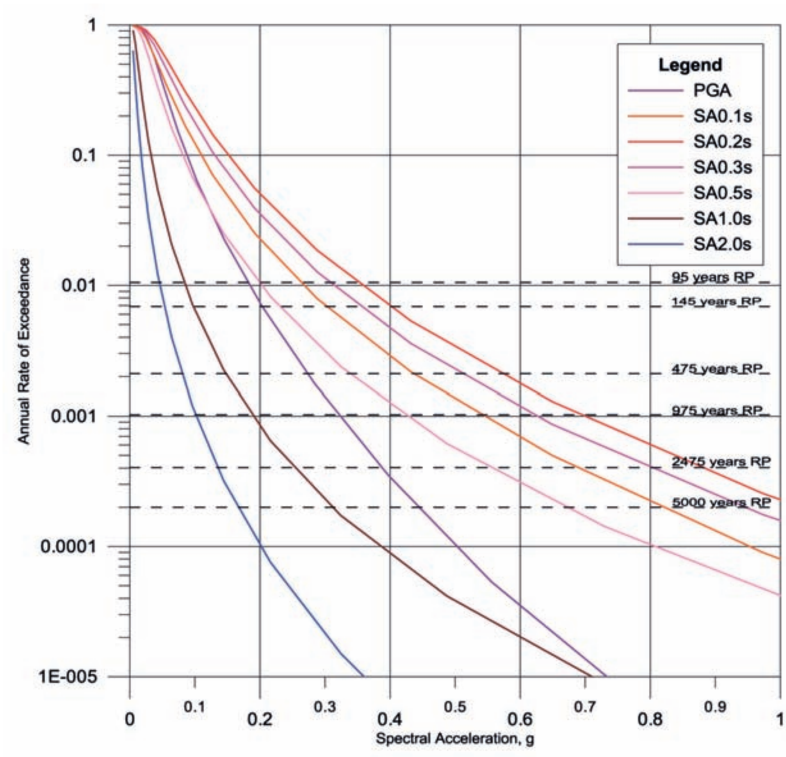

Fig. 37. Seismic hazard curves (rock conditions) for PGA and spectral accelerations SA 10 Hz, 5 Hz, 3.3 Hz, 2 Hz, 1 Hz and 0.5 Hz for Berat World Heritage site.

Table 7. Maximum horizontal bedrock PGA and SA for Berat World Cultural Heritage site.

Period	Spectral Acceleration, g				
Sec	RP = 95y	RP = 475y	RP = 975y	RP = 2475y	RP= 5000y
PGA	0.181	0.272	0.318	0.386	0.440
0.10	0.261	0.436	0.532	0.683	0.806
0.20	0.347	0.565	0.688	0.868	1.024
0.30	0.306	0.503	0.619	0.788	0.942
0.50	0.198	0.337	0.418	0.547	0.665
1.00	0.083	0.147	0.186	0.250	0.310
2.00	0.045	0.080	0.101	0.134	0.164

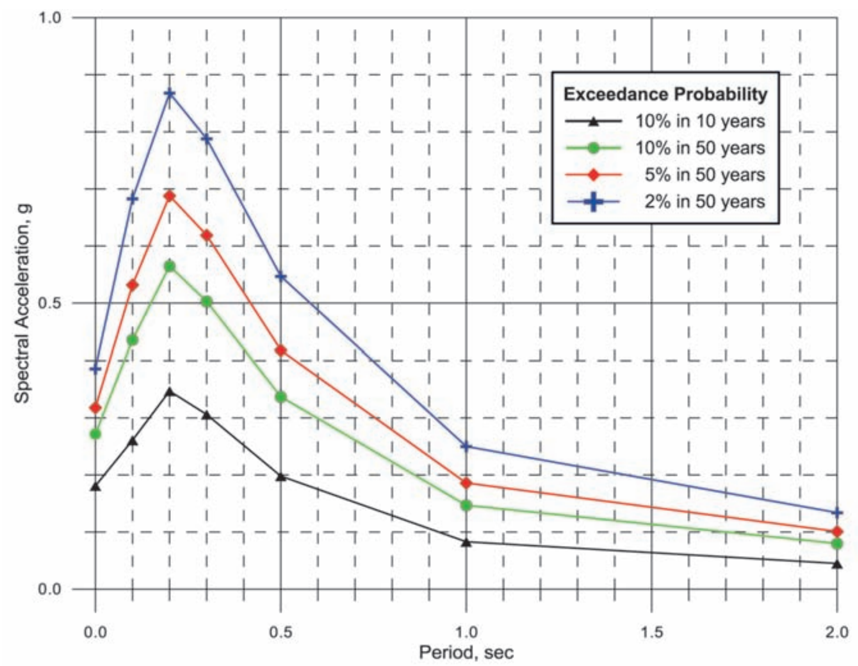

Fig. 38. Uniform hazard spectra for 1%, 2%, 5% and 10% probability of exceedance in 50 years, and 10% probability of exceedance in10 years for Berat World Heritage site.

m/s for limestones.

Zone 2) Siliciclastic terrigenous geological bedrock

The marly limestone constitutes the core of the anticline, and is covered by a siliciclastic terrigenous geological bedrock consisting of alternating medium and tick sandstone and siltstone beds, dipping towards the two limbs of the anticline, i.e., both west and east.

This unit occupies most of the urbanized area of the city, with thicknesses of hundreds of meters. By the way, the actual thickness of the turbiditic units in the subsoil of the city is not directly detectable. Not even the noise measurements performed a few hundred meters north of the city walls (AL19 in Annex II) highlight any possible velocity contrast between siliciclastic turbidites and limestones probably because of the steep bedding. When looking instead at the MASW prospection performed near the Hotel Tomori (L01 in Annex II), Vs values of 600 m/s on average likely referable to the siliciclastic turbidites, are detected between 5-10 and 25-30 meters from the surface and between Quaternary covers and underlyng limestone (Vs > 8000 m/s).

Zone 3) Quaternary covers

This zone coincides with the Quaternary soft alluvial covers mainly constituted by sand and pebbles, which overlie in disconformity both limestones and siliciclastic terrigenous deposits. The actual thickness of this unit is unknown, even if velocity plots of MASW acquisitions performed near the Hotel Tomori (L01 in Annex 10) suggest a thickness of 5-10 meters and Vs of 200 m/s on average. Noise measurements are in agreement with MASW prospections, with f_0 of 7.5 Hz, corresponding to thicknesses of 6-7 meters for

Vs = 200 m/s (AL03 in Annex 10).

Zones susceptible to geological instability

Zone 4) Zone susceptible to rock falls,

toppling and sliding of blocks. This zone occupies the wide steep slopes connecting the hilltops with the lower part of the town, both north and south of the river. Fractured limestones of the geological bedrock crops out along theses slopes (Fig. 39). Attitude of fractures and bedding planes suggests that this zone is highly unstable.

Zone 5) Zone susceptible to liquefaction

This zone coincides with the floodplain of the Osum River. Liquefaction could affect saturated sandy alluvial deposits because of a rapid and significant increase in interstitial pressure. These conditions occur in a strong seismic event and shear strength of loose sandy soils is pulled down, turning sediments into a heavy liquid.

Shear wave velocity of these soft sediments is probably less than 200 m/s, and thickness does not exceed 5-10 meters. These values are in agreement with MASW prospections (L03 in Annex II) and with noise measurements (AL02 in Annex II).

Superficial and buried geomorphological features

The most relevant morphological elements of the study area are the rock escarpments that

Fig. 39. View of the escarpments overlooking the historic city center of Berat.

characterize the old center of the city (see Annex IV). The escarpment overlooking the right bank of the Osum River (north of the river) shows a difference in altitude of up to 200 meters, and is constituted by stratified and intensely fractured limestone (i.e., the geological bedrock). A similar condition, but with lower gradients and extensions, can be found on the left bank of the river.

Suggestions for further study

The main geohazard affecting the city of Berat is represented by the instability of rock escarpments overlooking the historic city center. The risk related to this criticality is high in static conditions and is even higher if a seismic event should occur. For this reason, it is suggested if not already available to carry out a detailed study of structural and the geomechanical setting of the limestones cropping out along the escarpements.

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6. SEISMIC MICROZONATION OF BUTRINT

GENERAL DATA OF THE SITE

Butrint (Fig. 40), is located on a low hill at the end of the Ksamil peninsula which separates the Ionian Sea from Lake Butrint (the two are connected by the Vivari Channel). To the south lies the flat expanse of the Vrina Plain, punctuated by low hills with villages.

Butrint is the best-studied ancient city in Albania, as well as being a site of extraordinary beauty, and it is in many ways a microcosm of Albanian history. To understand its history it is necessary to appreciate the changing morphology of the landscape.

Like many Mediterranean coastal sites, the landscape surrounding Butrint has a complex environmental history. Sedimentary analysis of core samples shows that the lake of Butrint is a relic of the former coastal embayment of open water that surrounded the site prior to the formation of the plain, c. 4000 B.C. Since then, the fault-bound valley to the south of Butrint has gradually filled with sediment brought down from the surrounding catchments, pushing the coastline seaward. (Fig. 41).

Recent environmental data from coring indicate that early topography of Butrint was conditioned by the presence of a water channel along the southern slopes of the acropolis hill, making the highest point the only suitable settlement area. The low-lying area is likely to have been subject to rapid silting but it is yet unknown if this was managed in any way. However, as is evident from the archaeological remains, this was on area of expansion during the Hellenistic period when Butrint developed a more distinctly urban aspect. (Hansen, London/Tirane 2009, p. 15).

By the Roman period the alluvial plain was sufficiently well-developed to allow substantial settlement, possibly as a result of local tectonic activity, leading to the inundation of low-lying land.

Despite these inundations, the underlying trend was one of continued sediment input and floodplain growth. By the Venetian period, the topography of the landscape was similar to that of today. Subsequent agricultural engineering works has severely canalized the network of meandering river systems that once crossed the

Fig. 40. View of the Butrint Achaeological Park.

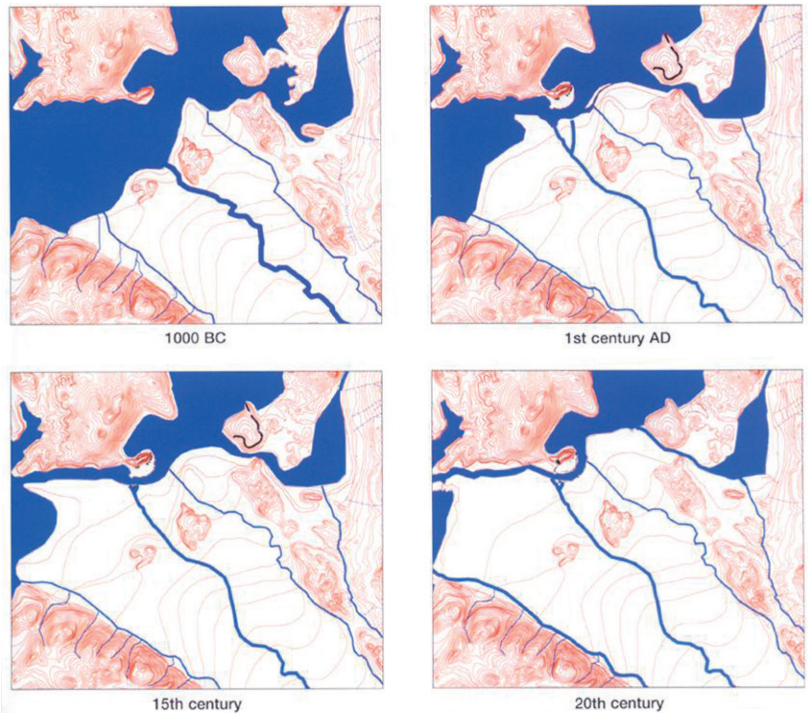

Fig. 41. The changing environment and topography of Butrint, c.1000 B.C.-c. A.D. 1950 (BF).

alluvial plain.

Some three thousand years ago, the low-lying area south of the channel was a lagoon connected to the Ionian Sea, which, through tectonic shifts and alleviation, eventually silted up (the landscape continues to change to this day, as the communist- era drainage system of the old cooperative state farm is breakings down and the fields are onece again occupied by salt marsh and swamp).

Standing at the head of the peninsula, Butrint in antiquity projected out into the lagoon. As fissures in the rock face of the city's acropolis formed natural wells and springs, it became a convenient point for mariners to replenish water. It is also the site of a healing sanctuary of the god Asclepius. The earliest settlement in Butrint was probably restricted to the acropolis hill. A small nucleus of the Late Bronze Age may have occupied the saddle and high eastern peak of the hill. It is likely that the early settlement was walled, and, perhaps, associated with a shrine, aggrandized in later centuries. The city eventually became one of the focal points of a local tribe, the Chaonians that coalesced around the seventh to sixth centuries B.C. Their tribal centre was at Phoinice (Finiq). While there may well have been long-distance contacts with the Aegean world in earlier times, the foundation of the Corinthian colony on Corfu in 600 B.C. provided a major stimulus to the economic and social development of Butrint. There were close links between the island and the mainland, and quantities of imported Corinthian ceramics have been found, although Butrint itself was not a Greek colony. During the subsequent Hellenistic age (Fig. 42a), when Butrint and Chaonia were an integral part of Epirus, the city was the focal point of a self-governing koinon, or state, called the Prasebes. At this time, it was enhanced with new buildings: (Fig. 43 a,b) a theatre, prytaneum, agora and a circuit of defensive walls encircling the acropolis hill and the shrine of Asclepius on its southern slope (Fig. 43 a,b). Because of the tectonic changes in the area, the prytaneum is flooded with groundwater. The stone pavement with was a gift from of one of Butrint's citizens, a freedman

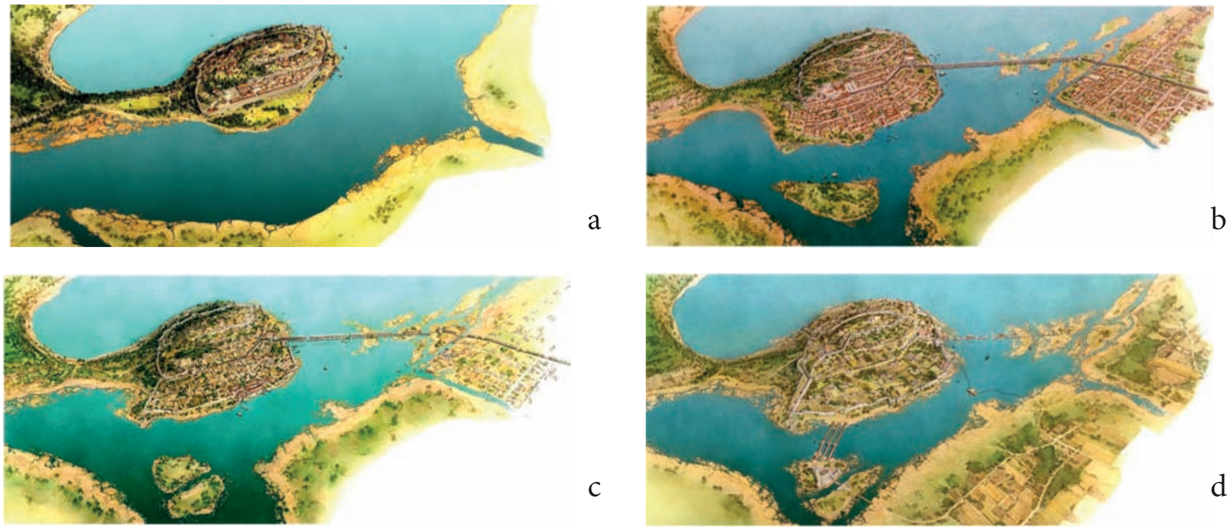

Fig. 42. The history of Butrint. a) the Hellenistic Butrint; b) the Roman Butrint; c) the late ancient Butrint; d) Butrint in the middle ages.

called Gnaius Domitius Eros, who included his name in capital letters set into the marble pavement in front of the prytaneum. Eros was connected to one of the most influential families of the Augustan age.

However, the entire region was soon drawn into the increasingly violent contest between the rising power of the Roman Republic and the established kingdom of Macedonia. By the early 2^{nd} century B.C., Rome had secured control of Corfu and dominated Chaonia from 168 B.C., when Macedonia was finally defeated and its territory ultimately made into a Roman province. Part of Epirus, which had supported Macedonia, was ravaged and looted, and many cities, such as Antigonea, were destroyed. Butrint and its neighbours, which allied themselves with the conquerors, escaped the violence.

Thereafter, Butrint's history was increasingly entangled with Roman politics. Epirus became a favorite haunt of many Romans, including, in the 1rst century B.C., Titus Pomponius Atticus, the friend and correspondent of the politician Cicero. The city was at the fulcrum of two other conflicts at this time, as Roman politicians took to arms to seize supreme power in the Republic (Fig. 42b). The war between Caesar and Pompey was partly fought out along this coastline, with Butrint playing a secondary role, although Caesar himself may have visited briefly in 47 B.C. In 44 B.C., after his victory, Caesar attempted to establish a colony in Butrint, on the other side of the Vivari channel-aplan that met opposition from Atticus and Cicero, but which nevertheless came to fruition two decades later under Augustus. He refunded the colony to Butrint, and from this time the city began to be aggrandized, with the construction of new buildings and facilities (Fig. 42c). A forum, aqueduct, villas and bathhouses were all planned, though their completion seems to have occurred over the course of some 60 years, and many may have been additions of the mid-first century A.D. when there was renewed imperial interest in the region, at the time of Nero. Cicero provides a picture of a sleepy port town, a description that might apply to Butrint throughout the Roman Empire and into late Antiquity. Like other cities, Butrint underwent significant changes in this time. In particular there was a hiatus of activity in the third century, around A.D. 280 or later, which resulted in the abandonment of parts of the city centre and suburbs.

The survey, geophysical and excavation work since 2001 on the Vrina Plain has clarified the organisation of the settlement here (Bescoby,


a


b

Fig. 43. Butrint Archaelogical Park. a) Hellenic and Roman theatre; b) Hellenic ancient fortification: the Lion Gate.

2007; Crowson and Gilkes, 2007). Establishment of organised land division was based on a grid of actus squares of 36.58. This may have occurred as part of the Augustan colonial programme but was certainly in place by the 1st century A.D. The growth of a semi-urban area, a suburb of the main city, focused on a sanctuary, with attendant houses, baths, roads and a necropolis in the later 1st century A.D. A change occurred in the nature of the settlement with some buildings being abandoned or converted into industrial function in the later 2nd or early 3rd century A.D.

The destruction of the settlement, was probably caused by an earthquake, for which there is now plentiful evidence in the form of collapsed walls and structures from the 3rd century A.D.

There was limited reoccupation and rebuilding in the 4th century A.D.. A more significant phase of reuse began in the 5th century and focused on a Paleochristian basilica (Fig. 44a).

It was discovered during the excavations work in 2007 that the main part of the ancient city have been see that the forum pavement possesses a slope of 1.7 degrees on the southern side the pavement is over half a meter lower than on the north side. This displacement of the forum may have been the result of an earthquake that struck the city in the mid-to late 4th c. A.D. Several sources refer to an earthquake and/or tsunami that struck Epirus in the year 365 A.D. (Hodges et al., 1997, 217). An earthquake on the second half of the 4th c. A.D. (Hasani, Monumente 2, 1989) may have brought about a tectonic shift in Butrint that appears to have resulted in the inundation of the forum and surrounding urban centre. This might explain why the civic centre shifted to the east side of Butrint in the Late Antiquity Period, where the terrain remained above the water table. The destruction phases of the forum were followed by backfilling the forum space, presumably to create a new surface above the resultant water level. In the 5th century A.D., hard water-resistant, cocciopesto, floors were laid over what had been the forum area in on order to prevent water intrusion during seasonal flooding episodes (Hernandez and Condi, 2008, 275-292). Nevertheless, the water level continued to rise, coinciding with and possibly accelerating of the urban centre in the 7th century A.D. (Gilkes and Lako, 2004, 170-2). Occupation continued in the forum area until Butrint was finally abandoned by the Venetians in 1572 (Crowson, 2007, 15-17).

Butrint continued to contract in Late Antiquity, though there was plenty of activity in the city's old core. A new city wall was erected at the end of the 5th century. Butrint was certainly still part of what was left of the Roman

Fig. 44. Butrint Archaelogical Park. a) Paleochristian basilica; b) Venetian Triangular Fortress; c) Turkish Castle.

commercial system, focused on the eastern Mediterranean, as plentiful imports of Syrian and Palestinian goods affirm, and this situation continued into the first two decades of the 7th century. The early medieval city was clearly a much-reduced entity, but it was not entirely abandoned, the settlement perhaps withdrawing to a nucleus around the foot of the acropolis. It is clear, though, that by the 9th and 10th centuries a new settlement of timber buildings and masonry churches was being erected amongst the ruins of the ancient city. A thick and relatively sterile alluvial deposit demonstrates that the ancient urban centre laid partially submerged in a shallow pond until the grand terracing program undertaken in the High Byzantine Period in the 10th or 11th centuries A.D. Butrint at this time formed an outpost of the Byzantine Empire (Fig. 42d). This trend reached its height in the 11th and 12th centuries, as the Mediterranean economy and long-distance trade continued to revive. Also at this time a scheme was put in place by new powers in the Mediterranean- the Normans, under Robert Guiscard and his sons, and, later, their successors, the Angevin French- to use Butrint and other coastal cities, such as Corfu, as bases for attacks against the Byzantine Empire. Butrint's revival as a town probably reached its height at this time, with a sizeable population living within the reconstructed walls.

However, the plan finally failed in 1281, yet Butrint and Corfu remained in Angevin hands until 1386, when both were purchased by the

Republic of Venice, to be employed as bastions first in the Venetians' long running war against the Republic of Genoa and later as foils to the growing threat of the Ottoman Empire. At this time the city went into inexorable decline. The bishop had already moved his seat away from the decaying town in 1347, and it seems that Butrint declined to little more than a castle on the acropolis hill, guarding and exploiting the abundant fisheries that had always been a major asset.

Butrint soon found itself on the edge of Ottoman Turkish power and Venice herself, embarked on two centuries of warfare with the expanding Sultanate. In 1537 the city was taken by Sultan Suleiman the Magnificent, who is said to have directed his engineers to build a bridge of boats over the Straits of Corfu to attack the island. Thereafter Butrint was periodically lost and recaptured by both sides.

By 1572 the old city was completely ruined, and a new administrative centre was formed on the southern side of the Vivari channel, around the smaller Triangular Fortress that controlled the fisheries (Fig. 44b). This remained the focal point of Butrint for the last centuries of its existence. The Turks seized the place again in 1716, under Sultan Ahmet III, and used it as a base for a second abortive assault on Corfu. However it was the collapse of the Venetian Republic in 1797, and the landing of a French revolutionary army in Corfu, which finally ended 500 years of Venetian presence.

French possession of the fortress and fisheries at Butrint was short-lived, and within a few years Butrint had been seized again by the Turks, in whose hands it remained until 1912, when the Ottoman Empire was in its turn driven out of Europe and the new state of Albania created (Fig. 44c).

Threats to the World Heritage property of Butrint and the joint UNESCO/ICOMOS/ICCROM missions

The property of Butrint was inscribed on the World Heritage List in 1992 as an example of outstanding universal value, meeting the cultural criterion C (iii), according to the Operational Guidelines (2005), since it bears "a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared."

The property registered a series of monitoring/assessment missions carried out by UNESCO and its advisory bodies since 1997. After civil strife in the country, looting in the site was reported by the Butrint Foundation. Following the first mission outcomes, at its 21st session (December 1997), the Committee decided to include Butrint on the List of World Heritage in Danger.

A second joint UNESCO/ICOMOS mission was deployed in April 2001 and later in October 2003. The same year Butrint became a designated site under the RAMSAR Convention (1971), due to its lagoon, also known as the Lake of Butrint, which is now recognised worldwide as a wetland of international importance.

Further recommendations followed in relation to the protection and conservation of the site and on its governance system, including the development of a management plan, a multistakeholders' board and a shift in the zonation.

The latter in particular referred to the establishment of a buffer zone of the World Heritage site in between the National Park and RAMSAR borders, including the nearby villages bordering the National Park.

Following the UNESCO-ICOMOS-ICCROM joint assessment mission on the site in 2005 and its recommendations, as well as consideration of the recorded improvements achieved and upon condition to finalise the management and conservation plan of the property, and to prevent any illegal development or inappropriate construction on the site, in accordance with an effective application of the legal provisions of the new law on cultural heritage, the World Heritage Committee decided to remove Butrint from the List of

World Heritage Sites in Danger.

Finally, it asked to the State Party to invite a joint UNESCO/ICOMOS/ICCROM mission in 2007 to assess the implementation of the Committee's decision.

The foreseen joint UNESCO/ICOMOS/ICCROM mission requested by the Committee was sent to Albania from 17 to 21 April 2007 in order to assess the state of conservation of the property, the implementation of the decisions of the World Heritage Committee and, among alias, assess any threats of illegal development or inappropriate construction on the property[1].

Finally, at the request of the State Party of Albania, a joint UNESCO-ICOMOS advisory mission was carried out from 24 to 26 August 2010 in order to further review the overall situation of the World Heritage properties of Butrint. This was focused on the state of conservation of the site in its widest urban context, its integrity and authenticity and the state of its buffer zone caused by the widening and modernisation of the road from Saranda to Butrint as well as the overall impact of the road in relation to the Outstanding Universal Value of the World Heritage property. The mission concluded that the construction of the road might constitute an imminent danger to the World Heritage property, and accordingly recommended a number of measures to be taken to ensure compliance with the 1972 Convention. In order to improve the overall situation, measures had to be taken to provide further technical assistance for the enhancement of the existing management plan in order to ensure the most adequate conditions for effective management and protection of the site[1].

GEOLOGICAL OVERVIEW OF BUTRINT AREA

The Butrint broader region, that is, the Saranda district, is located in the western part of the Ionian domain. The Ionian domain represents a large marine basin filled with sedimentary deposits, which was formed during Liassic (Jurassic) times.

From a lithostratigraphic point of view, from base to top, the Ionian domain consists of evaporites, a Jurassic lower carbonate succession (massive neritic limestone - Pantokrator formation), an upper carbonate succession (Cretaceous-Eocene pelagic limestone) and turbidite sedimentary deposits (Oligocene-Miocene-Pliocene).

In the Butrint area the Meso-Cenozoic succession mainly consists of lower Triassic evaporites, Upper Triassic-Lower Liassic platform carbonates and Eocene and Oligocene terrigenous deposits (Fig. 45). The upper Miocene depositsm which are related to early neotectonic deformation, are represented by the Tortonian sandstones unconformably covering the older alpine deposits. Pliocene deposits are unconformably placed above the Tortonian and older deposits, and are composed of alternating silt and clay, and sandstones.

The Quaternary deposits have continental and marine origin, and consist of colluvium, beach deposits mainly constituted by sands and pebbles, lagoonal peat deposits (which are common around Butrint Lake), and alluvial deposits of the Vrina Valley, which represents a typical active asymmetric valley of tectonic origin.

The Acropolis of Butrint, in particular, was built on a hill which consists of the Jurassic "Pantocrator limestone" (Fig. 45), while the town was mainly developed on the Holocene sediments on the southern and southeastern side of the hill. The southern side of the acropolis is bordered by an E-W to ENE-WSW trending fault, which is probably the extension of a greater strike-slip right-lateral structure of the northern Corfu Island (Pavlides et al., 2001). The fault affects the Jurassic limestone, and is expressed in the topography as a steep scarp that extends into the archaeological site.

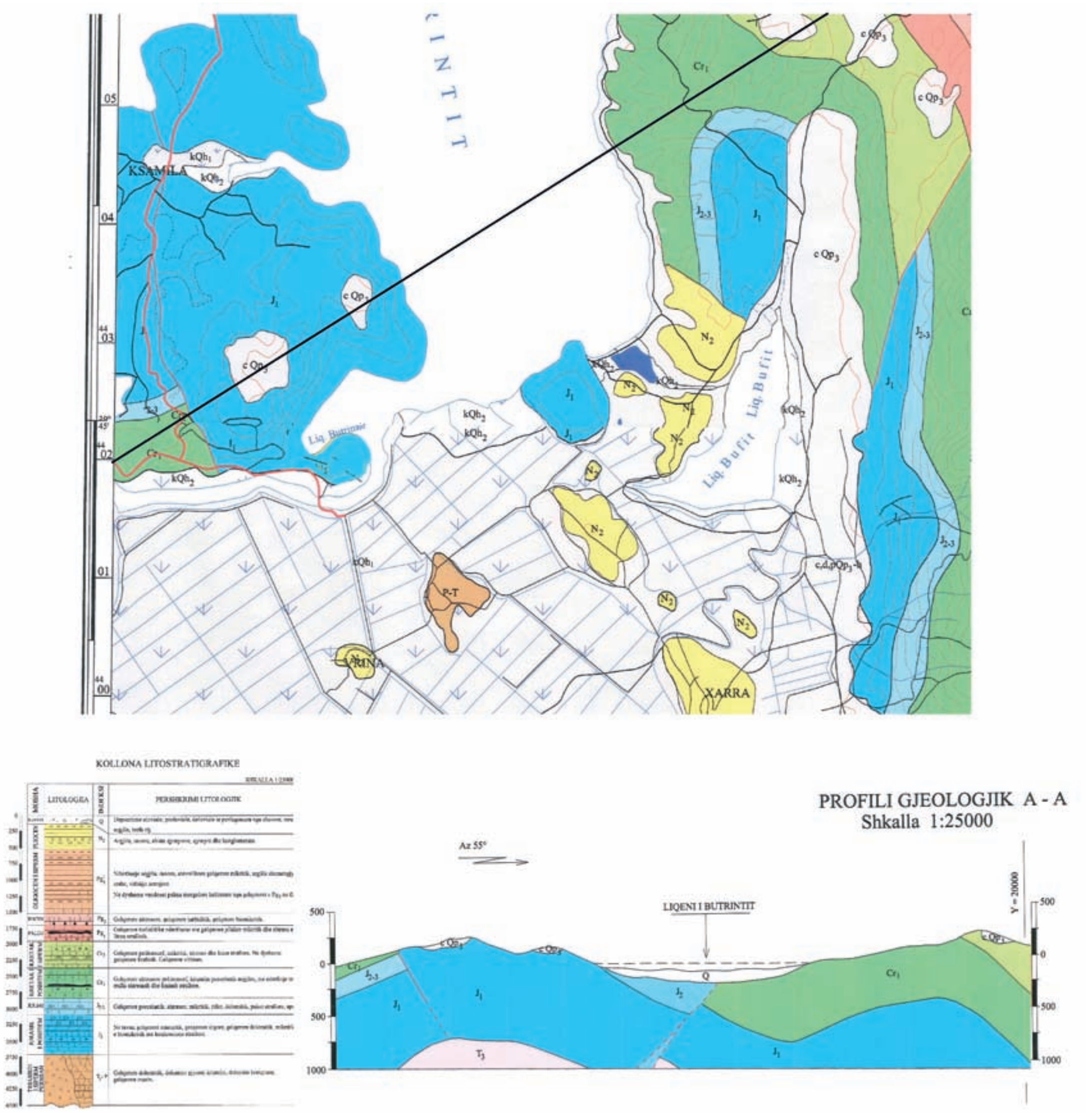

Fig. 45. Geological map and cross-section of Butrint area (from Llahana, 2010).

SEISMIC HAZARD OF BUTRINT CULTURAL HERITAGE SITE

In Figure 46 there is a fragment of the map of active faults in Albania for the Butrint area (Aliaj et al., 2004) with the main earthquakes that have occurred in this area. The active structural elements are represented on this map by the type of deformation (normal fault, reverse fault, thrust and backthrust, strike-slip, flexure, evaporite diapir dome) and their chronology of activity. They are noted by color.

Hazard curves

In Figure 47 there are the hazard curves we developed for PGA and response spectral accelerations for a suite of periods with engineering interest, for Butrint cultural heritage sites. Then the annual frequency of exceedances are plotted (dashed horizontal lines), which correspond to probabilities typically used for the design, like 10% in 10 years (RP = 95 years) and, respectively 10% (RP = 475 years), 5% (RP = 975 years), 2% (RP =2 475 years) and 1% (RP = 5000 years) in 50 years.

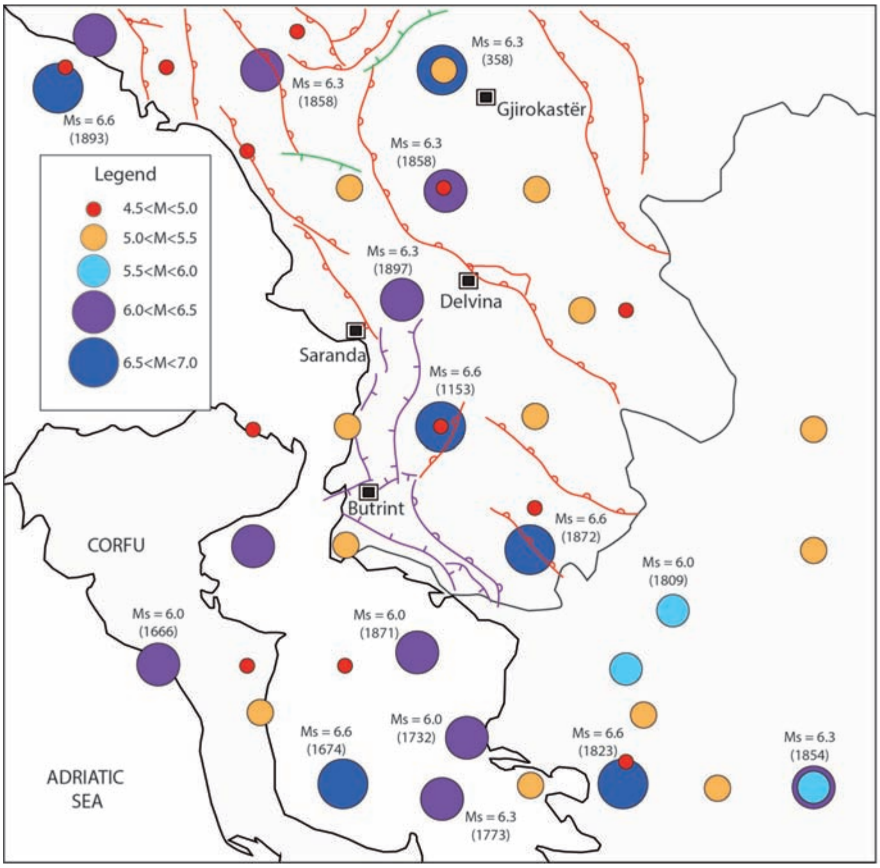

Fig. 46. Active faults in the Butrint site area and its vicinity (from Aliaj et al., 2004). The colors express the chronology of fault activity, noted as follows: blue-Quaternary, green-Pliocene-Quaternary, and red-pre-Pliocene, but active also during Pliocene-Quaternary. The epicenters of the earthquakes around Butrint are also noted.

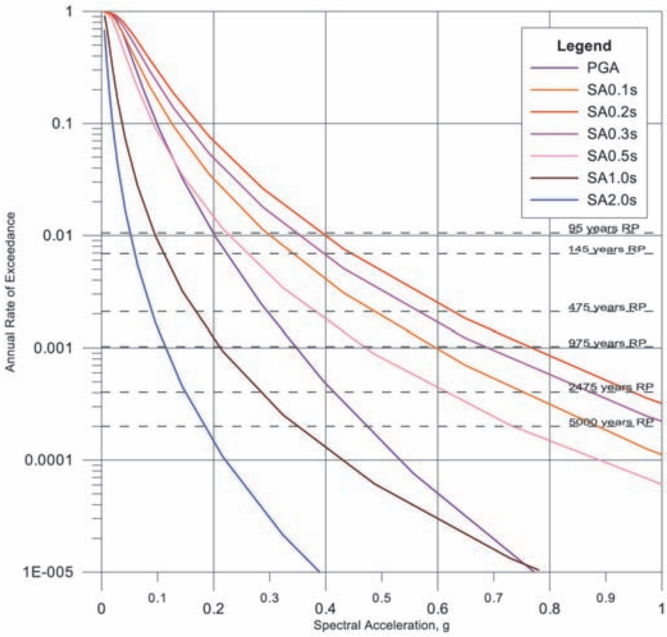

Fig. 47. Seismic hazard curves (rock conditions) for PGA and spectral accelerations SA 10 Hz, 5 Hz, 3.3 Hz, 2 Hz, 1 Hz and 0.5Hz, for Butrint World Heritage site.

Table 8. Maximum horizontal bedrock PGA and SA for Butrint World Cultural Heritage site.

Period	Spectral Acceleration, g				
Sec	RP=95y	RP=475y	RP=975y	RP=2475y	RP=5000y
PGA	0.199	0.294	0.342	0.412	0.468
0.10	0.294	0.480	0.585	0.739	0.872
0.20	0.389	0.624	0.749	0.944	1.098
0.30	0.342	0.556	0.679	0.859	1.018
0.50	0.223	0.375	0.466	0.604	0.734
1.00	0.094	0.165	0.210	0.280	0.347
2.00	0.050	0.089	0.112	0.149	0.181

Uniform Hazard Response Spectrum (UHRS)

For Butrint we considered five hazard levels: 10% of exceedance probability in 10 years, and 10%, 5%, 2% and 1% respectively, in 50 years, corresponding to 95 year-, 475 year-, 975 year-, 2475 year- and 5000 year- return periods, respectively. The maximum horizontal bedrock PGA and spectral accelerations (SA) for each RP were obtained from PSHA and are listed in Table 8. The uniform hazard spectra (UHRS) for each RP for Butrint cultural heritage sites is plotted in Fig. 48.

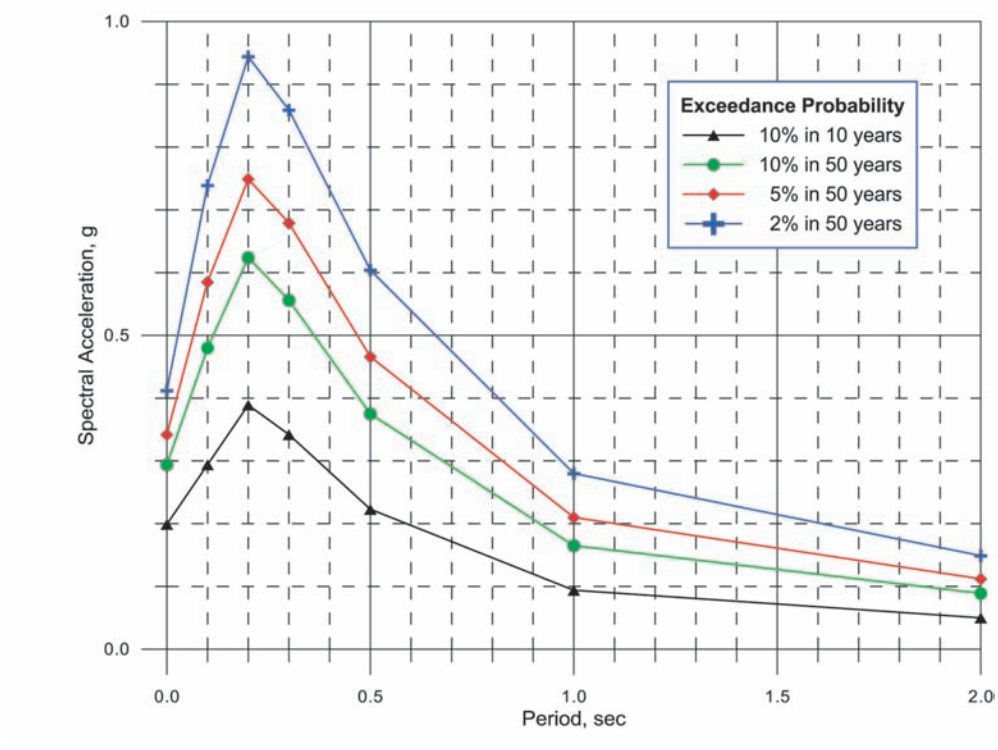

Fig. 48. Uniform hazard spectra for 1%, 2%, 5% and 10% probability of exceedance in 50 years, and 10% probability of exceedance in10 years for Butrint World Heritage site.

SEISMIC MICROZONATION OF LEVEL 1 IN BUTRINT

The seismic microzonation map of level 1 of Butrint (Annex V) was carried out in the light of i) already available maps, ii) results of new geological surveys and iii) new measurements of microtremors (Fig. 16).

Data analysis has allowed us to establish the presence of both stable zones susceptible to local amplifications and unstable zones susceptible to geological instability. Zones are numbered in ascending order, based on the amplification expected.

Stable zones susceptible to local amplification

Zone 1) Butrint hilltop

This zone mainly coincides with the acropolis of the town.

In this area the geological bedrock crops out along a 80-100 meters-wide, flat-topped northeast⁄southwest trending ridge.

Zone 2) Butrint northern slope

This zone is located in the northwestern sector of the Butrint promontory, between the hilltop (south) and Butrint Lake (north).

Geological survey highlighted the presence of a thick (> 5 meters) cover of cemented carbonate breccias, constituting a local aquifer as testified by the presence of a historical water well close to the so called "Lion Gate" (Fig. 43b).

Zone 3) Butrint lagoon

This zone covers the southern sector of the main archaeological area of Butrint and the northern Vrina plain, close to the Vivari channel (Annex V).

Information gained from scientific literature (Pavlides et al., 2001) and processing of microtremor measurements allowed us to assume the presence of clayey, silty clayey and sandy lagoonal deposits rich in organic matter for a thickness of about 30-50 meters. Because of the high thickness of these soft deposits, this zone is expected to be the most susceptible to seismic amplification.

Natural subsidence of recent lagoonal deposits in this zone is probably responsible for the drowning of archaeological remains of Butrint.

Zones susceptible to geological instability

Zone 4) Zone susceptible to rock falls, toppling and sliding of blocks

This zone occupies the steep slope connecting the acropolis of Butrint with the lower part of the town overlooking the Vivari channel. Fractured limestone of the geological bedrock (i.e., the Pantokrator limestone; Pavlides et al., 2001) crops out along this slope. Evidence for toppled blocks and attitude of fractures and bedding planes suggest that this zone is highly unstable (Fig. 49 a,b).

Zone 5) Zone susceptible to liquefaction

This zone covers the belt of coast overlooking the Vivari channel and the Butrint Lake (Annex V). Liquefaction could affect saturated sandy lithosomes located close to the water line because of a rapid and significant increase of the interstitial pressure. Under a strong seismic event these conditions occur and shear strength of loose sandy soils is pulled down, in fact turning sediments into a heavy liquid.

Zone 6) Zone susceptible to differential settlements

This zone covers the sector between the Butrint lagoon (south) and the escarpment bordering the upper Butrint town (north). The covering unit here is supposed to be constituted by interfingered fine grained lagoonal deposits and calcareous breccia, because of its location close to the steep calcareous slope. Soft covers should range in thickness from few a meters to tens of meters, from north to south, even if the lack of data make this hypothesis highly questionable. By the way, although the actual thickness of the lagoonal deposits is not known, it is highly probable that the thickness variation expected in a short distance from the escarpment bounding the acropolis of Butrint may be responsible for differential settlement of the anthropic structures, as evidenced by archaeological findings in the town (Figs. 49 a,b). Because of the presence of soft covers, this zone is also highly susceptible to local site amplification.

Superficial and buried geomorphological features

The main geomorphological feature of the Butrint site is the fault scarp related to the strike-slip fault affecting the archaeological area (Fig. 49 c,d). This structure divides the carbonate rise, on top of which the Acropolis stands, from the coastal plain bordering the Vivari channel (Annex V).

Due to the lack of subsoil information, it is not possible to precisely define the extent of this fault scarp in depth. However, surface information associated with results of microtremor analyses allow us to assume that the buried scarp extends several tens of meters in depth toward the Vivari channel.

Suggestions for further study

The seismic microzonation of level 1 presented in this report allows us to divide the Butrint territory into seismic microzones qualitatively "homogeneous" in seismic perspective, but affected by a high level of uncertainty because of the lack of subsoil information. There are main sources of uncertainties in this seismic microzonation study: lack of information about lithology, thickness, and shear wave velocity of the soft units covering the geological bedrock (i.e., the


a


b


c


d

Fig. 49. a,b) View of the theatre, the deformed structure is probably due to earthquake effects of the 4th century A.D. (from Pavlides et al., 2001); c,d) view of the fault scarp on the northen flank of the theatre.

Pantokrator limestone). Lithostratigraphic and geometric uncertainty could be pulled down by means of one deep borehole located close to the Vivari channel, at the southern margin of the archaeological area, associated with Electrical Resistivity Tomographies (ERTs) oriented perpendicular to the fault scarp. Shear wave velocity could be detected by means of MAWS measurements.

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NOTE

[1] Report on the UNESCO - ICOMOS advisory mission to Butrint, 24 /26 August 2010.

7. SEISMIC MICROZONATION OF GJIROKASTRA

GENERAL DATA OF THE SITE

The city of Gjirokastra (Figs. 50 and 51) is situated in the south of Albania, overlooking the Drino Valley. It is often known as "the Stone City" and its most distinctive feature is the silvery-coloured limestone which gives the city its character. The stone is quarried nearby and is used in the construction of buildings, roofs and streets.

The fortress of Gjirokastra was listed as a cultural monument in 1948 with individual houses, mosques and churches listed separately in 1973.

In 1965, the historical monuments were declared under protection by the Institute of Monuments. It was supervised by experts of the field in harmony with the directives of Venice Charter.

The World Heritage property Museum-City of Gjirokastra was inscribed on the World Heritage List in 2005, and in 2008 the property was extended to include the city of Berat and renamed as Historic Centres of Berat and Gjirokastra. They were inscribed on the basis of criteria(iii) and (iv) as per Decisions 29 COM 8B.48 and 32 COM 8B.56.

Fig. 50. Aerial view of Gjirokastra. The fortress of Gjirokastra was listed as a cultural monument in 1948 with individual houses, mosques and churches listed separately in 1973.

Criterion (iii): Berat and Gjirokastra bear outstanding testimony to the diversity of urban societies in the Balkans, and to longstanding ways of life which have today almost vanished. The town planning and housing of Gjirokastra are those of a citadel town built by notable landowners whose interests were directly linked to those of the central power. Berat bears the imprint of a more independent life style, linked to its handicraft and merchant functions.

Criterion (iv): Together, the two towns of Gjirokastra and Berat bear outstanding testimony to various types of monument and vernacular urban housing during the Classical Ottoman period, in continuity with the various Medieval cultures which preceded it, and in a state of peaceful coexistence with a large Christian minority, particularly at Berat in 2005 Gjirokastra was included in the UNESCO world heritage site and continues to be in the list of

Fig. 51. View of Gjirokastra from the southwestern hilltops of the city. In 1965, the historical monuments were declared under protection of the Institute of Monuments. The area was supervised by experts of the field in harmony with the directives of Venice Charter.

cities in danger.

Over the last thousand years it has been invaded by Ottoman Turks, Italians and Germans, and this mixture of prosperity and insecurity has led to the development of the architecture that has been preserved to this days.

The town itself was built by big landowners and has a castle that has origins in the 13th century, Citadel. This is one of the biggest castles in the Balkans. With the decline of the Byzantine Empire, it became the residence of the very powerful Zenebeshi feudal clan. The city has some typical dwellings called Turkish Kule, typical for the Balkan region. Gjirokastra contains many of them dating back to the 18th century and also some more elaborate ones from the of 19th century.

The surrounding historical sites show the earliest evidence of the prehistoric period such as the Goranxi gorge. Evidence of other important sites in Antigonea and Adrianopol are testimonies of the importance of the region even during the greek and roman occupation.

The archaeology of Gjirokastra is relatively unknown. Due to the proximity of the Classical and Hellenistic settlement at Jermë (Antigoneia) and the Roman city of Hadrianopolis it has frequently been assumed that the medieval fortress represents the first occupation of the site. However this has now been challenged by the results of excavations within the fortress that have led to the discovery of ceramics from four different phases of occupation before the Ottoman period: 5th -2th centuries B.C., 5th -7th centuries A.D., 9th -10th centuries and 12th -13th centuries.

The medieval fortress, which has been dated to the second half of the 13th century, encompasses an area of 2.5 hectares. The remains of five towers and three main entrances of the original fortress can still be seen, though the fortress was substantially rebuilt and extended to the south west in 1811-1812 by Ali Pasha of Tepelenë. Ali Pasha was also responsible for the construction of an aqueduct feeding the fortress from a water source on Mt. Sopot, some 10 km distant from Gjirokastra. Complete sections of this aqueduct were still visible at the beginning of the 20th century but were destroyed in 1932. The fortress was used as a garrison in the 19th century. During the communism period the castle has also served as a prison for dissidents.

Threats to the World Heritage Property of Gjirokastra and the Reactive Monitoring Mission

The the site has recoderd a set of natural-human induced threats affecting the property:

- lack of financial support for the monuments;
- lack of a management plan;
- seismic threat;
- erosion, landslides;
- uncontrolled urban development of Gjirokastra;
- abandonment of the site by the inahbitants;
- misuse of monument by the owner with the risk of damaging the authenticity and the integrety of the building.

The Reactive Monitoring Mission to the World Heritage property "Historic Centres of Berat and Gjirokastra" generated a number of specific recommendations for Gjirokastra, as it follows:

1 To ensure adequate legal measures are in place in order to immediately suspend all illegal construction activities in the property and its buffer zone (by 15 July 2013).
2 To prepare a general conservation plan for the entire area of the World Heritage site including its buffer zones (by 31 March 2014).
3 To prepare guidance on standards for all conservations materials and methods which are allowed to be used within the protected area (by 30 September 2013).
4 To prepare a detailed list of the monument of 1st and 2nd category with detailed descriptions of all urban structures (by 30 September 2013).
5 To prepare a detailed evaluation of all houses-monuments with record of inappropriate measures implemented (by 30 September 2013).
6 To prepare detailed recommendations on how to mitigate all illegal actions undertaken in contravention to international conservation

standards and to the laws of Albania (by 30 November 2013).

7 Define the main attributes that reflect Outstanding Universal Value - including streetscapes, views and also intangible elements - indicated in lists, photographs and on maps (by 31 October 2013).

8 Prepare a more precise classification of all historic and other buildings (by 30 November 2013).

9 Develop monitoring indicators that fully reflect the attributes (by 30 November 2013).

10 To prepare a general conservation plan for the entire area of the World Heritage site including its buffer zones (by 31 March 2014).

11 To prepare guidance on standards for all conservations materials and methods which are allowed to be used within the protected area (by 30 September 2013).

Problems and Risks

The main problems an risks affecting Gjirokastra can be summarized in:

- lack of financial support for the monuments;
- lack of a management plan for Gjirokastra;
- earthquake threat;
- erosion.

In particular, risks coming from “legal” threats are:

- uncontrolled development of Gjirokastra;
- abandonment of the monuments by the owners;
- conflict of property between different owners regarding the property;
- interference by the owners in a specific monument considered as a monument of first category;
- importance without the presence of the specialists.

This risks of damaging the authenticity of the building and it’s integrity;

- illegal purpose of use of monument by the owner.

GEOLOGICAL OVERVIEW OF GJIROKASTRA AREA

The region of Gjirokastra is located south of the Shkoda-Peja fault, which divides the Dinaric Mountains from the Hellenides Montains, within the territory of which the region falls. The Hellenides Mountains, which in turn can be divided in internal and external, are part of the Dinaric-Albanian-Hellenic thrustbelt, which was formed during the Alpine orogeny. The external Hellenides, in particular, include the tectonic-sedimentary domains Krasta-Cukali, Kruja, Ionian, Sazani and Durres.

The region of Gjirokastra falls into the Ionian zone. This zone includes areas characterized by synclines and anticlines with NW-SE orientation (Fig. 52), which from east to west are: Permeti syncline, anticline of Berat, the syncline of Memaliaj, anticline of Kurveleshi, syncline of Shushica and Cika anticline. These structures exhibit a westward asymmetry and are complicated by thrust faults located at their western flanks. The amount of tectonic transport of the thrust faults, both in the area of Kruja and in the Ionian zone is estimated to be between fifteen and fifty km (Xhufi and Canaj, 1999; Frasheri et al., 2009).

The historic center of Gjirokastra is located, from a geological point of view, along the eastern flank of the Mali i Gere anticline, which is connected to the western flank of the Drino syncline. The deposits identified, mainly Mesozoic carbonates and Paleogene terrigenous units (Fig. 52), constitute a homoclinal with a general NNW-SSE trend, gently dipping to E-NE (ca. 20°). The terrigenous portion of the geological substrate, which houses the castle and much of the historic city center, lies in unconformity above the underlying carbonate units (Torresi, 2008; Fig. 52).

SEISMIC HAZARD OF GJIROKASTRA CULTURAL HERITAGE SITE

In Fig. 53 there is a fragment of the map of active faults in Albania for the Gjirokastra area (Aliaj et al., 2004) with the main earthquakes that have occurred in this area. The active structural elements are represented on this map by the type of deformation (normal fault, reverse fault, thrust and backthrust, strike-slip, flexure, evaporate diapir dome) and their chronology of activity. They are is noted by color.

Hazard curves

In Fig. 54 there are the hazard curves we developed for PGA and response spectral accelerations for a suite of periods with engineering interest for Gjirokastra cultural heritage sites. Then, the annual frequency of exceedances are plotted (dashed horizontal lines), which correspond to probabilities typically used

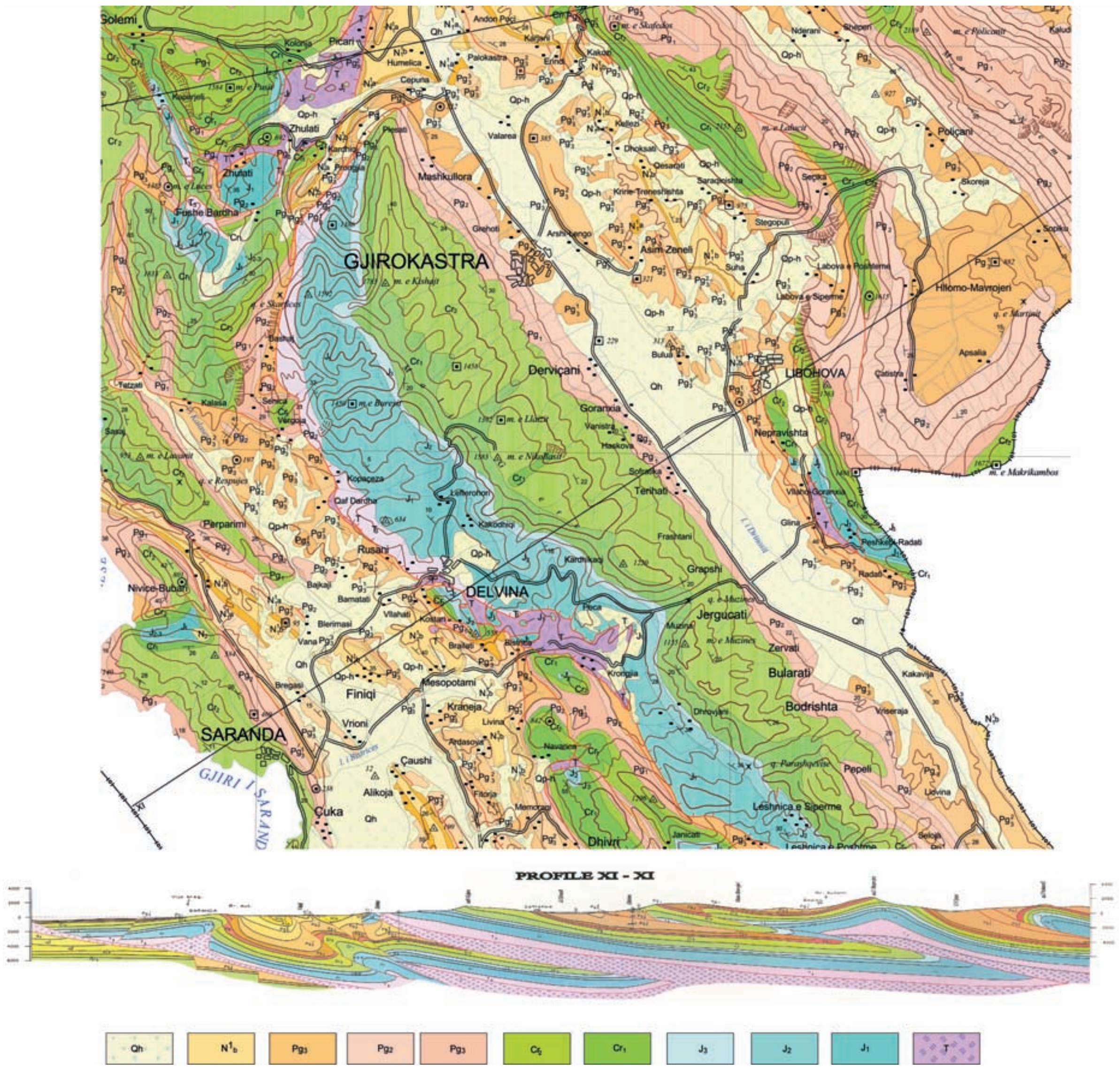

Fig. 52. Geological Map of Gjirokastra and Geological Cross section. (from various authors, 2004). Legend: Qh – alluvial deposits, Quaternary; N1b –Marly deposits, Burdigalian; Pg31 – Marly-sandstone Flysch deposits, Oligocen; Pg2 – Sandy-Marly Flysch, Eocen; Pg1- Turbidites deposits, Paleocen; Cr2 – Rudist Limestone, Upper Cretaceous; Cr1 – Dolomitic Limestone, Lower Cretaceous; J3 – Flint limestone, Upper Jurassic; J2 –Pelagic Limestone, Middle Jurassic; J1 – Flint Limestone, Lower Jurassic; T- Evaporites.

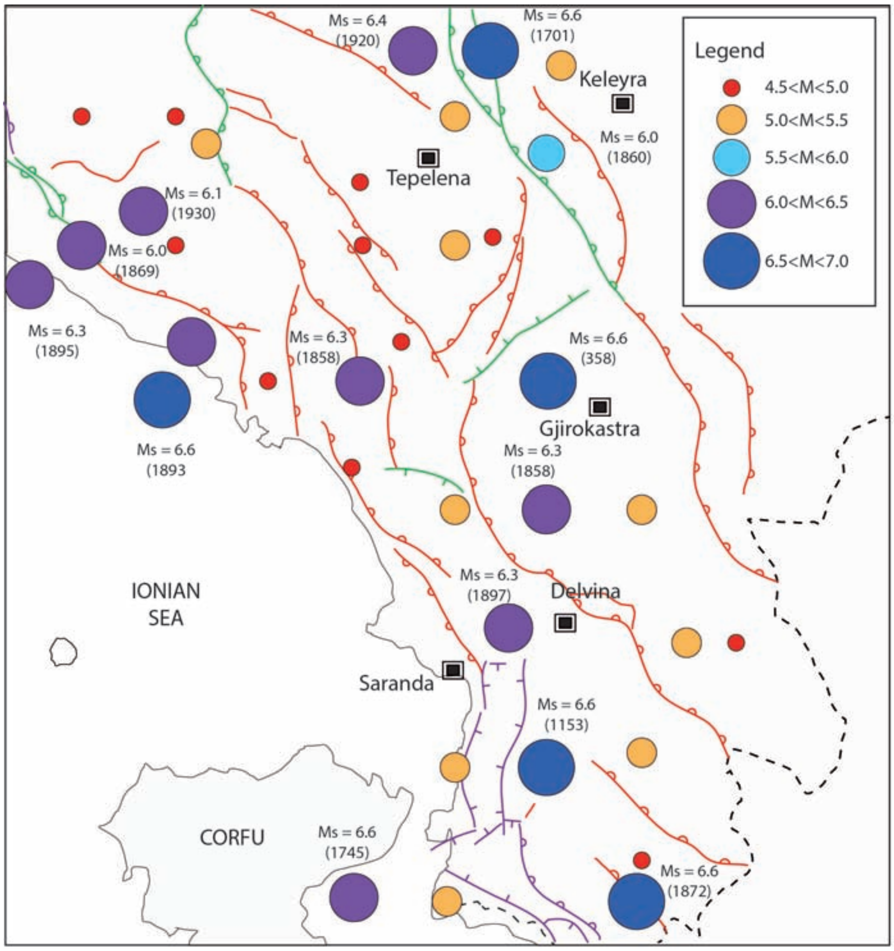

Fig. 53. Active faults in the Gjirokastra site area and its vicinity (from Aliaj et al., 2004). The colors express the chronology of faults activity, noted as follows: blue- Quaternary, green- Pliocene- Quaternary, and red – pre-Pliocene, but active also during Pliocene-Quaternary. The epicenters of the earthquakes around Gjirokastra are also noted.

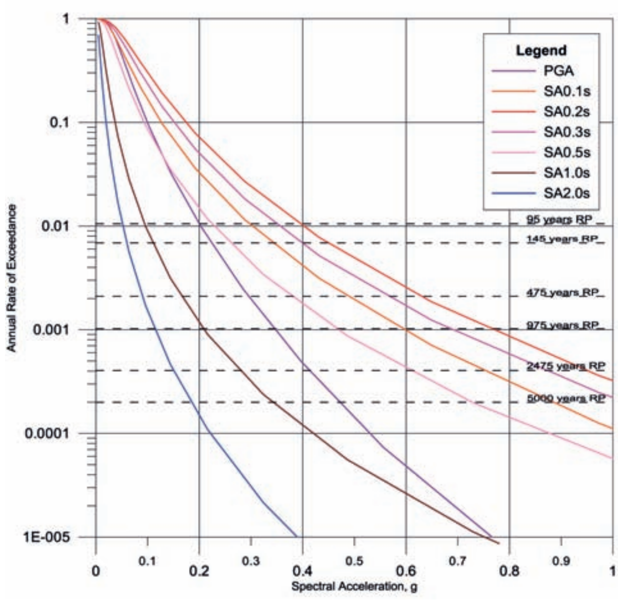

Fig. 54. Seismic hazard curves (rock conditions) for PGA and spectral accelerations SA 10 Hz, 5 Hz, 3.3- Hz, 2 Hz, 1 Hz and 0.5 Hz, for Gjirokastra World Heritage site.

for the design, like 10% in 10 years (RP = 95 years), and respectively 10% (RP = 475 years), 5% (RP = 975 years), 2% (RP = 2475 years) and 1% (RP =5 000 years) in 50 years.

Uniform Hazard Response Spectrum (UHRS)

For Gjirokastra we considered five hazard levels: 10% of exceedance probability in 10 years, and 10%, 5%, 2% and 1% respectively, in 50 years, corresponding to 95 years-, 475 years-, 975 years-, 2475 years- and 5000 years- return periods, respectively.

The maximum horizontal bedrock PGA and spectral accelerations (SA) for each RP were obtained from PSHA and are listed in Table 9. The uniform hazard spectra (UHRS) for each RP for Gjirokastra cultural heritage site is plotted in Fig. 55.

Table 9. Maximum horizontal bedrock PGA and SA for Gjirokastra World Heritage site.

Period	Spectral Acceleration, g				
Sec	RP=95y	RP=475y	RP=975y	RP=2475y	RP=5000y
PGA	0.200	0.294	0.341	0.412	0.466
0.10	0.297	0.482	0.587	0.740	0.872
0.20	0.392	0.627	0.752	0.946	1.099
0.30	0.345	0.558	0.681	0.860	1.018
0.50	0.224	0.374	0.464	0.600	0.727
1.00	0.094	0.164	0.207	0.276	0.340
2.00	0.051	0.090	0.113	0.150	0.182

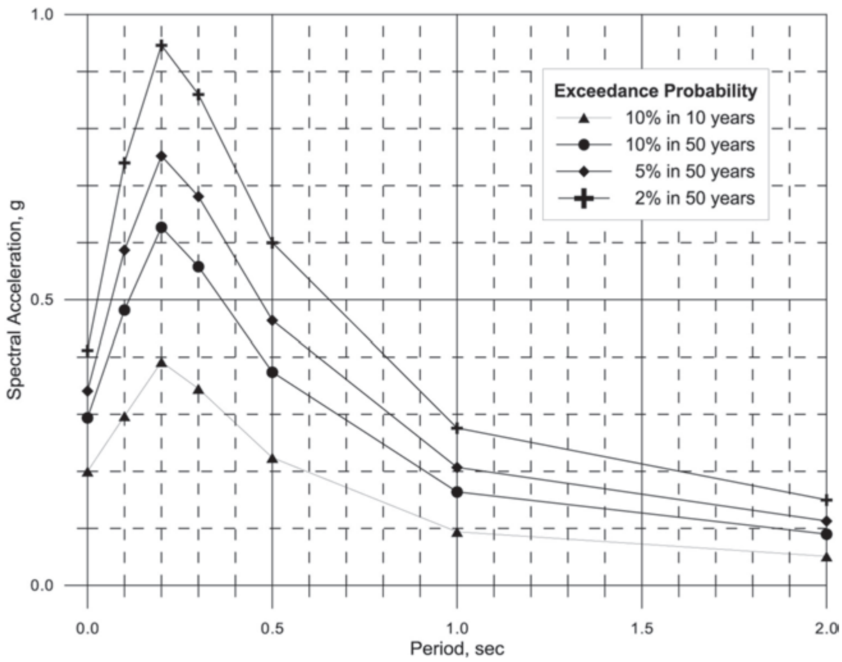

Fig. 55. Uniform hazard spectra for 1%, 2%, 5% and 10% probability of exceedance in 50 years, and 10% probability of exceedance in 10 years for Gjirokastra World Heritage site.

SEISMIC MICROZONATION OF LEVEL 1 IN GJIROKASTRA

The seismic microzonation map of level 1 of Gjirokastra (Annex VI) was been carried out in the light of i) already available information, and ii) new measurements of microtremors (Fig. 17).

Data analysis has allowed us to establish the presence of both stable zones susceptible to local amplifications and unstable zones susceptible to geological instability. Zones are numbered in ascending order, based on the amplification expected.

Stable zones susceptible to local amplification

Zone 1) Marly-calcareous bedrock

This zone occupies the western sector of the city and is characterized by the presence of thick-layered and fractured marly calcareous units, with dip slope attitude towards the northeast, locally overlaid in disconformity by cemented calcareous conglomerates. Marly limestone and overlying conglomerates are locally covered by a blanket of red earth, several meters thick.

The structural setting of marly-calcareous bedrock generates a homocline dipping towards the northeast, locally dissected by deep incisions occupied by streams that transport huge volumes of debris downstream (Annex VI). These narrow valleys are bounded by steep slopes (> 15°), which can cause topographic amplification of seismic motion.

Zone 2) Siliciclastic terrigenous geological bedrock

The marly limestone is unconformably covered by siliciclastic turbidite deposits, consisting of alternating medium and tick sandstone and siltstone beds, dipping 15°-20° towards the northeast. This terrigenous formation constitutes the geological bedrock of the city together with the marly limestone.

This unit occupies most of the urbanized area of the city, exceeding thicknesses of several hundred meters eastward (Annex VI). The turbidite deposits are locally, disconformably covered by cemented and fractured calcareous conglomerates (the same deposits that cover the marly-calcareous bedrock to the west), forming a layer a few tens of meters thick.

Turbidite succession and overlying conglomerates are dissected by deep incised valleys that isolate narrow ridges elongated in a northeast-southwest direction (Fig. 15); these ridges are expected to generate topographic amplification of seismic input. This effect was also highlighted by microtremor measurements made inside the fortress (AL13 and AL14 in Annex II, VI).

Zone 3) Alluvial fan 1

This zone is located in the southern sector of the study area, just south of the city, and is characterized by the presence of alluvial fan deposits that cover the siliciclastic turbidite unit. The alluvial fan deposits consist of uncemented calcareous conglomerates, in sandy matrix, which develop on the likely thickness of 15 to 20 meters, as also evidenced by the results of microtremor measurements (AL18 in Annex II).

Zone 4) Alluvial fan 2

This zone is located in the northern sector of the study area, just north of the city, and is characterized by the presence of alluvial fan deposits that cover the marly-calcareous bedrock. The alluvial fan deposits consist of uncemented calcareous conglomerates in sandy matrix, which develop on the likely thickness of 15 to 20 meters.

Zone 5) Wide- and narrow-incised valley

The area of the wide-incised valley covers the zone which runs between the stadium and the floodplain of the Drino River, carved into the terrigenous turbiditic unit (Fig. 56a).

The width of the valley, where it merges into the floodplain of the Drino River, exceeds 300 meters. The valley narrows gradually upstream, to form a narrow depression flanked by steep slopes carved into the marly-calcareous bedrock. The filling of the valley is not known, given the lack of drilling. However, the morphological and depositional setting allows us to assume a fining-upward filling with coarse basal deposits (sand and pebble) passing upward to silt and sand.

Microtremor measurements performed inside the stadium (AL16 in Annex II) permit us to estimate a local thickness of the alluvial deposits of 15 to 20 meters for likely shear-wave velocity (Vs) values. The lack of subsurface data, however, does not allow to define the effective thicknesses of the soft covers. The area of the narrow incised-valleys runs along the northeastern flank of the relief hosting the urban area; these valley are carved into the terrigenous turbiditic unit (Annex VI).

The width of the valleys at the confluence with the floodplain of the Drino River does not exceed 150 meters and their filling is not known, given the lack of drilling. However, it is assumed the presence of few tens of meters thick loose silty and sandy filling.

The unfavourable aspect ratio (i.e., relationship between height and width) of incised valleys and the poor quality of their filling can induce significant amplification of ground motion.

Zone 6) Alluvial plain

This zone is developed primarily west of the Drino River, along the foothills hosting the alluvial fans fed by rivers flowing from the mountains just west of Gjirokastra.

The heterogeneity of the subsoil allows to divide this zone into two areas, one near the hills on which stands the city, the other, represented by the valley of the Drino River.

Regarding the sector close to the hills, the presence of both alluvial fans and the Drino River allows us to hypothesize the presence of alternating loose silts, sands and pebbles. The superimposition of soils with different texture seems confirmed by results of microtremor measurements (AL12 in Annex II), which highlight impedance contrasts in filling soils at shallow depths (approximately 5 meters from ground surface).

With regard to the thickness of these deposits, the articulated topography observed on the reliefs just west of the floodplain, suggests a significant thickness variability perpendicular to the incised valleys merging from the west to the main watercourse.

The outer sector is located mainly to the east of the Drino River, in the floodplain. Here the deposits are thought to be mainly fine-grained and related to the Drino River depositional mechanisms; thicknesses are not known, but they likely exceed 30 meters.

Zones susceptible to geological instability

Zone 7) Zone susceptible to rock falls, toppling of blocks

This zone occupies areas of the city close to escarpments carved into the marly-calcareous bedrock and adjacent to the conglomerates overlying the terrigenous turbidite units (Fig. 56 b,c). One of the critical areas in terms of susceptibility to rock falls and the toppling of blocks is occupied by the city's fortress, where a geological survey documented fallen blocks on both sides of the relief (Fig. 56d).

Zone 8) Zone susceptible to complex landslides

The areas of the city located on steep slopes carved into the turbidite unit may be affected by gravitational instability. These processes are currently active in some areas of the city and involve structures built near steep slopes.

Superficial and buried geomorphological features

In terms of seismic hazard, three morphological features of the study area are noteworthy:

- the presence of buried narrow valleys filled with soft soils, where enhanced amplification of seismic effects are presumable because of their aspect ratio;

Fig. 56. a) View of the city of Gjirokastra from one of the hills on which the high part of the city stands, highlighting one of the valleys cut into the thesiliciclastic turbidite deposits. b) Stratigraphic contact between the underlying terrigenous unit and the overlying conglomerates, on which the castle is founded (the walls are featured at the top of the photo). c) View of the stratigraphic contact between the underlying terrigenous unit and the overlying conglomerates, on which the castle stands; note the presence of tilted blocks of conglomerates lying on the slope. d) Detail of the castle walls that show fractures that could be related to gravitational instabilities that are active along the hillside on top of which the castle is founded.

- the presence of isolated narrow ridges, that can generate topographic effects because of their aspect ratio;
- the presence of escarpments carved into the calcareous and siliciclastic rocks that can be responsible for local gravitational instability.

Suggestions for further study

Uncertainty related to the lack of subsoil information mainly affects results of this seismic microzonation.

A drilling campaign should be planned to detect depth and filling of incised valleys merging in the Drino floodplain. Alternatively, a proper geophysical survey should be planned to define thicknesses of soft covers in an indirect way. The shape of the buried valleys could be detected by means of Electrical Resistivity Tomographies (ERTs) oriented perpendicular to the valley's elongation. Shear wave velocity (i.e., Vs) of soils and rocks could be measured using MASW technique, both for bedrock and terrigenous sedimentary covers.

Finally, a detailed geomechanic and structural survey of conglomeratic ridge underlying the fortress should allow us to better understand the processes responsible for its gravitational instability.

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8. GEOPHYSICAL MEASUREMENTS

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES (MASW) IN APOLLONIA AND BERAT

In order to reach a balance between signal propagation, geophone interval and the spread length for the "active source method" site-specific testing were performed at the sites of Berat and Apollonia in order to confirm the appropriate recording parameters. We decided to set up the geophones along a line with 3.0 m spacing in Berat measurements points in the Castle, at the Hotel "Tomori" and near the Bridge. The same distance between geophones was set up in the two measurements points in Apollonia. The described geophone configuration leads spread length 69 m. The shots are located at the end of the spread at different offsets; starting from a distance of 5% up to 40% of the entire spread length from the nearest geophone.

A 24-channel Geometrics Geode seismograph records vertically stacked impacts from a PEG-40 Propelled Energy Source mounted on a Toyota car with aluminum striker plate. The shots generated by this ensemble trigger 4.5 Hz vertical geophones (Model GS11-D) that are implanted into the ground. A total recording length of 2 s with 0.5 ms sampling interval is used to enclose the surface wave train. No acquisition filters are used.

The two-dimensional L-shaped spread configuration with the same 4.5 Hz vertical geophones is implemented for the "passive source method" at one measurement point in Apollonia. In this case, after the "active source survey" is performed half of the spread is turned 90 degrees and the geophones are set up with the intervals of 5 m from each other, reaching the 50 m array size, as it is shown on the Fig. 14. With 10 m intervals between the geophones and channel 12 positioned at the corner of the L shape, channels 1, 3, 5, 7, 9, 11, 13,

A

B

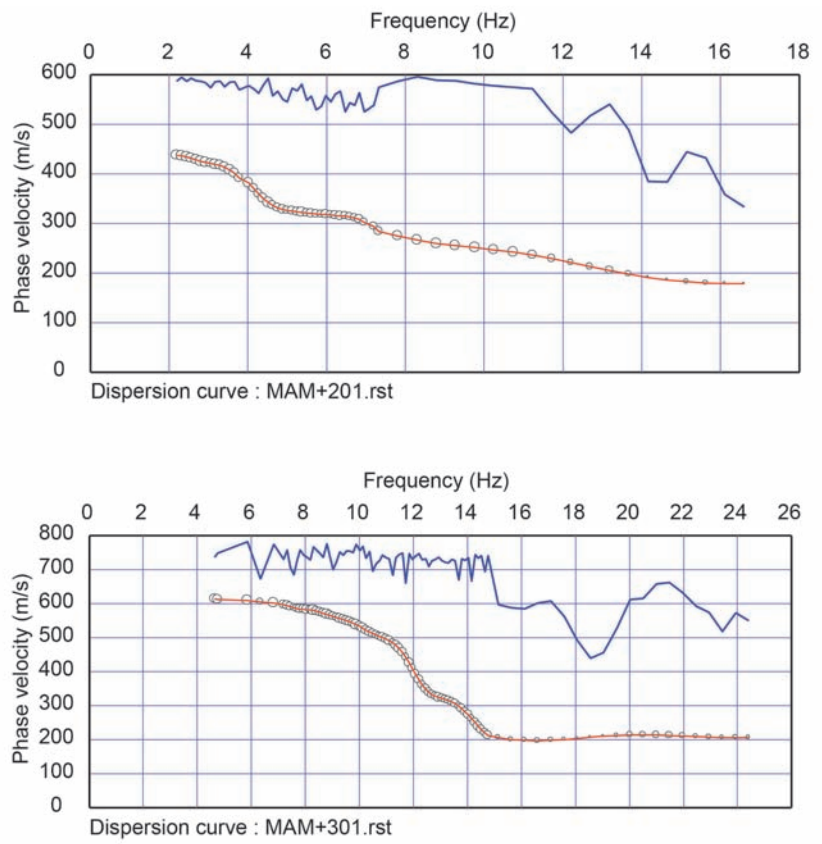


Fig. 57. Combined dispersion curves for the "active" and "passive" methods for the two measurement points in Apollonia: A) measurement point in the open field (northern site in Fig. 14); B) near the archeological object (southern site in Fig. 14).

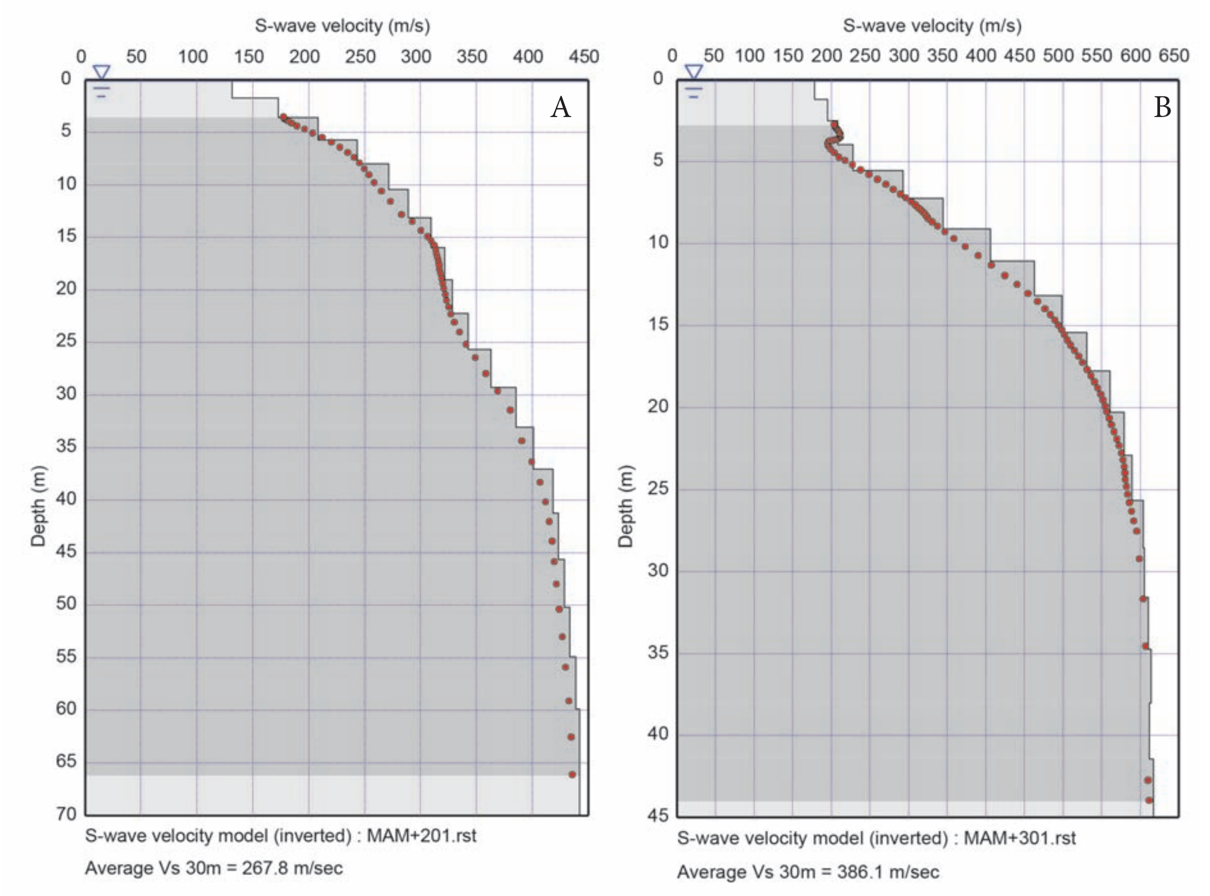


Fig. 58. Velocity plots for the two measurement points in Apollonia: A) measurement point in the open field (northern site in Fig. 14); near the archeological object (southern site in Fig. 14).

15, 17, 19, 21, 23 and 24 are deactivated.

The combined "active" and "passive" dispersion curves for the two measurement points in Apollonia are presented in the Fig. 57, while in the Fig. 58 presented are the velocity plots for the above mentioned points in Apollonia.

At the other measurement points in Berat (except the Castle, where there was not performed the "passive" method), and the other measurement poin tin Apollonia the linear spread was used for the measurements with the MAM method.

The sample interval is 2 ms for this case and a total of 20 records with a recording length of 32 s are considered for the analysis.

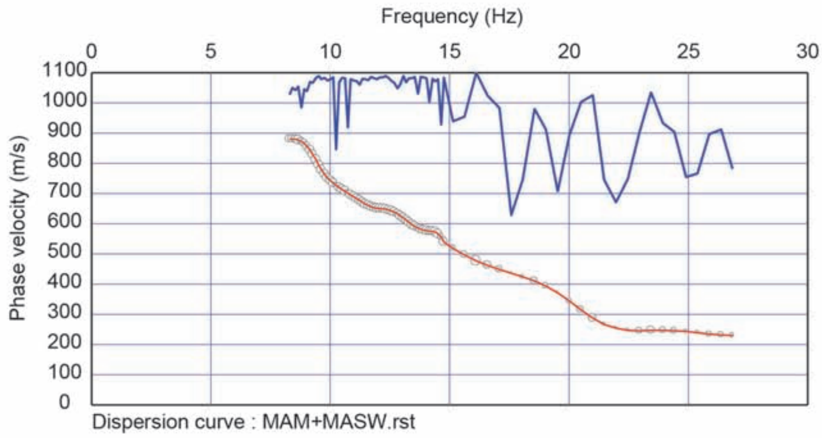
Using this procedure the investigated depth arrives up to 50 meter at the centre of the spread. A portable ASHTECH GPS device with post processing option is used for coordinate determination.

After the field studies the acquired data are processed for multi-channel analysis of surface waves using the software called SeisImagerSW that is licensed by Geometrics Inc.

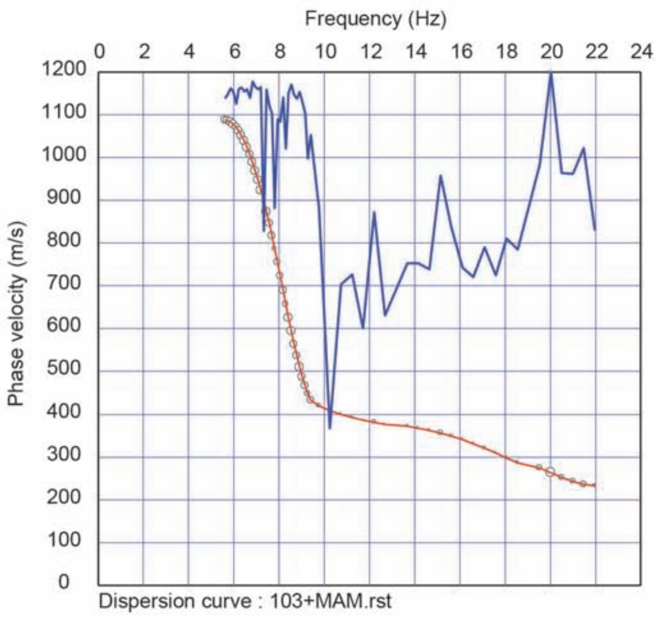
The combined "active" and "passive" dispersion curves for the three measurement points in Berat are presented in the Fig. 59, while in the Fig. 60 presented are the velocity plots for the above mentioned points in Berat.

It is already known that MASW datasets ("active source") have higher frequency content while MAM (microtremor array measurement, or "passive source") datasets have lower frequency content. Once active and passive source dispersion curves are picked through the SeisImager/SW software, the next step is to combine the two curves to obtain the highest resolution over the entire sampled depth range.

A



B



C

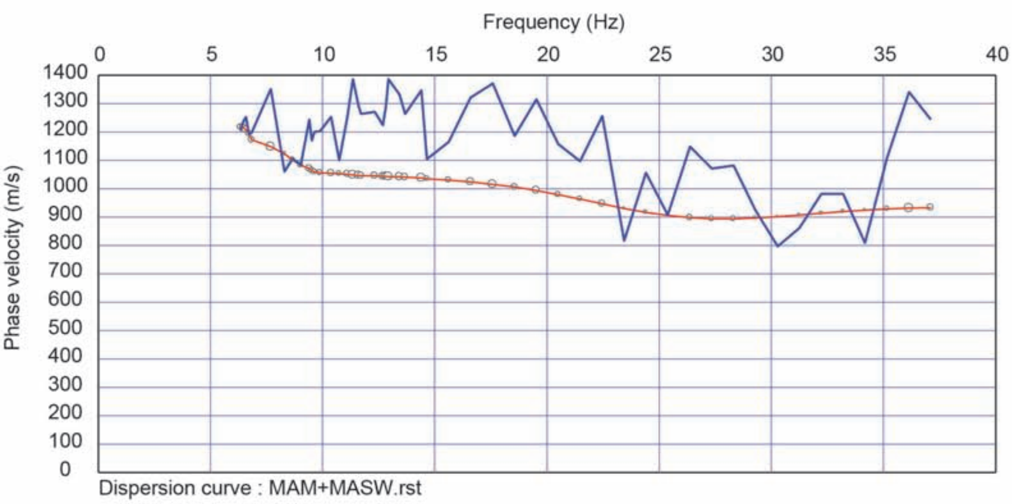


Fig. 59. Combined dispersion curves for the "active" and "passive" methods for the three measurement points in Berat: Hotel "Tomori" (A); near the Old Bridge (B) and at the Castle (C, lower curve). For the location see Fig. 15.

The combined "active" and "passive" dispersion curves for the three measurement points in Berat are presented in the Fig. 59, while in the Fig. 60 presented are the velocity plots for the above mentioned points in Berat.

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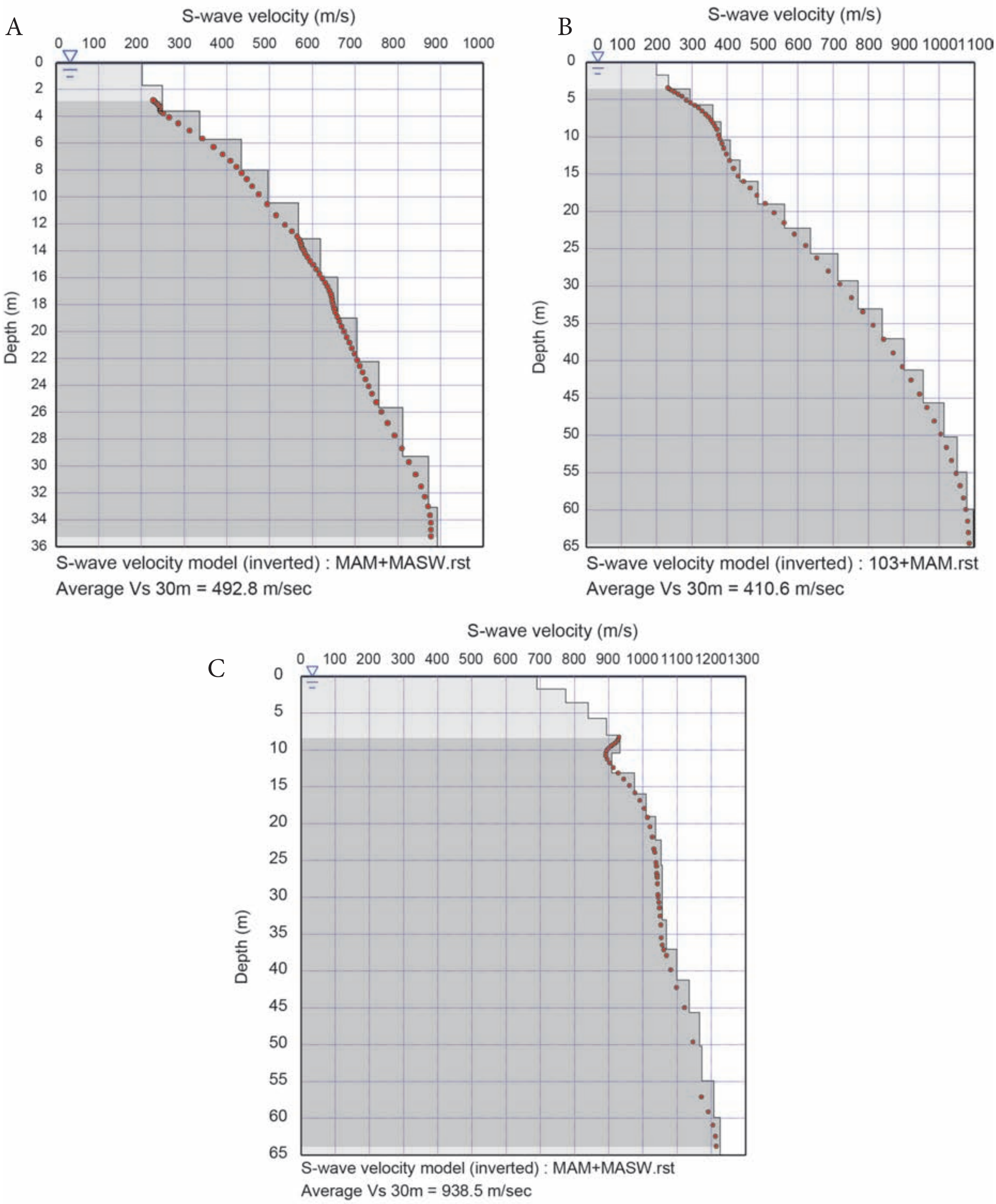


Fig. 60. Velocity plots for the three measurement points in Berat: Hotel "Tomori" (A); near the Old Bridge (B) and at the Castle (C). For the location see Fig. 15.

ANNEX II

PHYSICAL MEASUREMENT TABLES

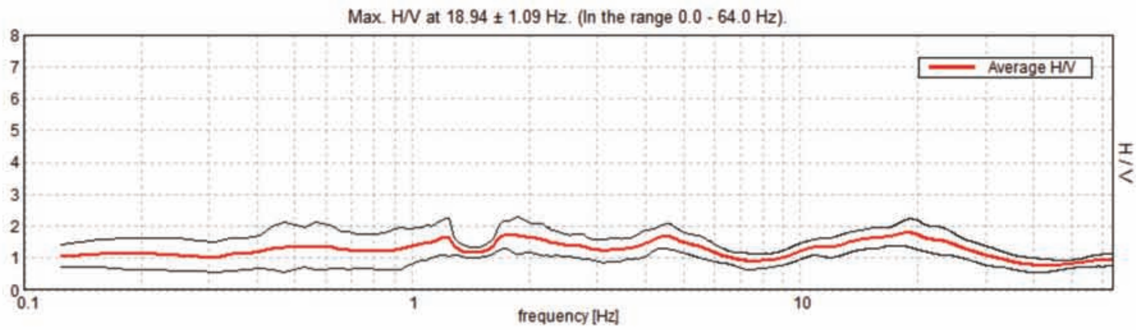
SEISMIC AMBIENT NOISE IN APOLLONIA

AL04 – ALBANIA, APOLLONIA

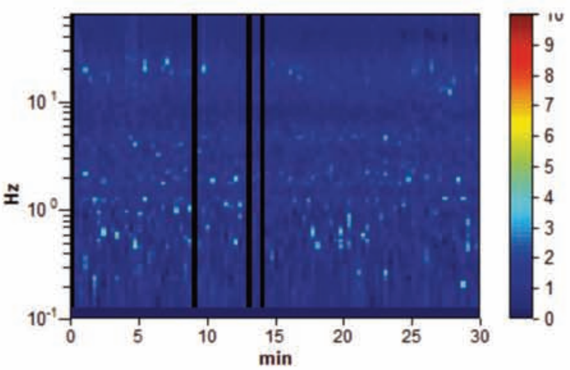
Instrument: TRZ-0005/01-09
Start recording: 20/11/11 12:52:58 End recording: 20/11/11 13:22:59
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30' 00''. Analyzed 96% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

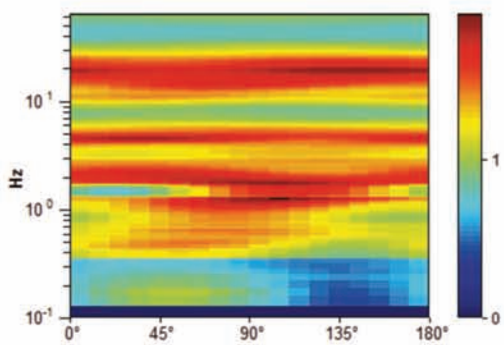
HORIZONTAL TO VERTICAL SPECTRAL RATIO



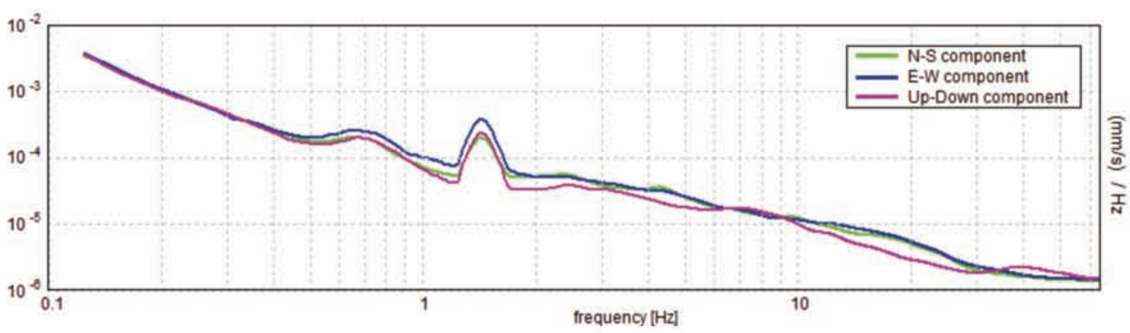
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 18.94 ± 1.09 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	18.94 > 0.50	OK	
$n_c(f_0) > 200$	32572.5 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5$Hz $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5$Hz	Exceeded 0 out of 910 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	7.563 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	34.75 Hz	OK	
$A_0 > 2$	1.79 > 2		NO
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.02888| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.54686 < 0.94688	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.2179 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

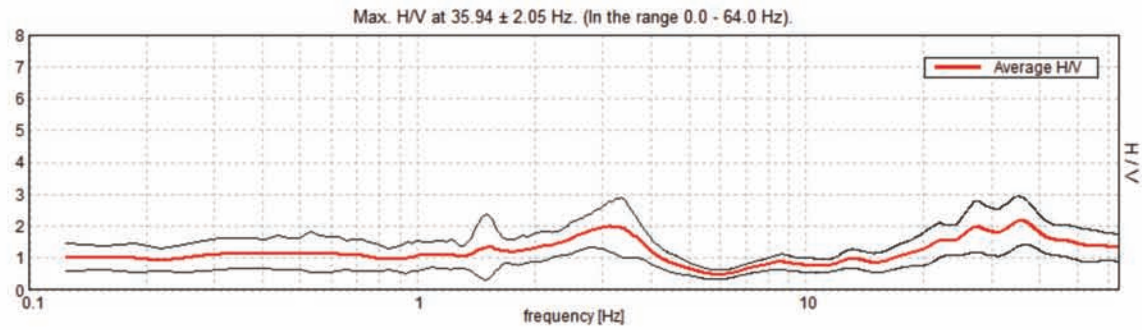
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL05 – ALBANIA, APOLLONIA

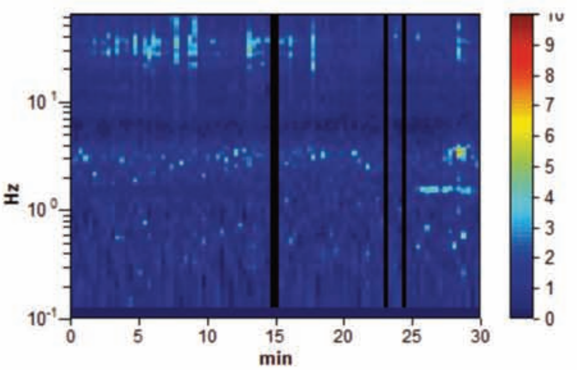
Instrument: TRZ-0005/01-09
Start recording: 20/11/11 14:10:27 End recording: 20/11/11 14:40:28
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30' 00''. Analyzed 96% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

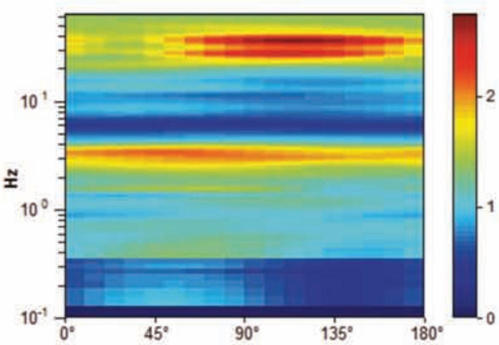
HORIZONTAL TO VERTICAL SPECTRAL RATIO



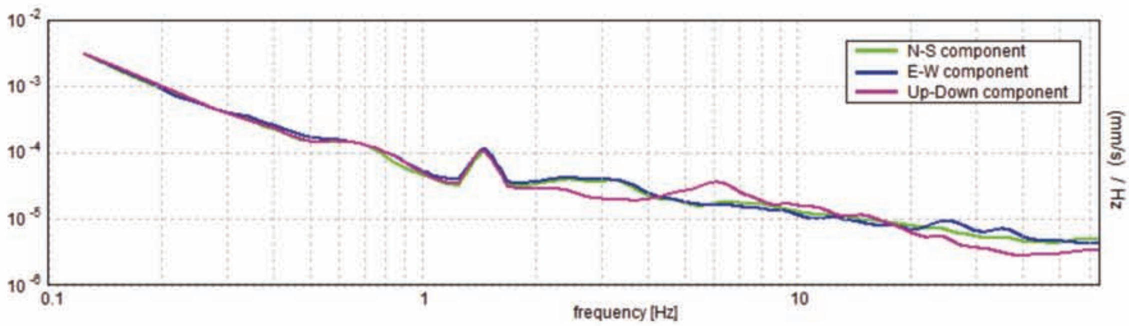
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 35.94 ± 2.05 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	35.94 > 0.50	OK	
$n_c(f_0) > 200$	61812.5 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 1474 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	17.563 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$			NO
$A_0 > 2$	2.17 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.02848| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	1.02339 < 1.79688	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.3748 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

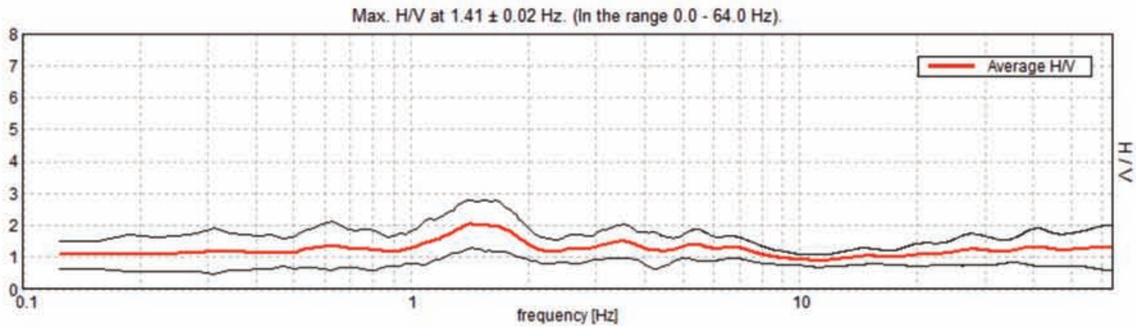
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL06 - ALBANIA, APOLLONIA

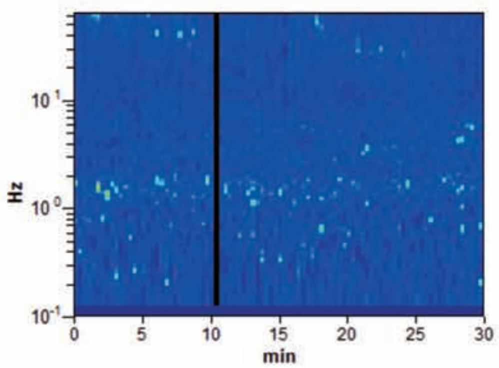
Instrument: TRZ-0005/01-09
Start recording: 20/11/11 16:50:37 End recording: 20/11/11 17:20:38
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30' 00". Analyzed 99% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

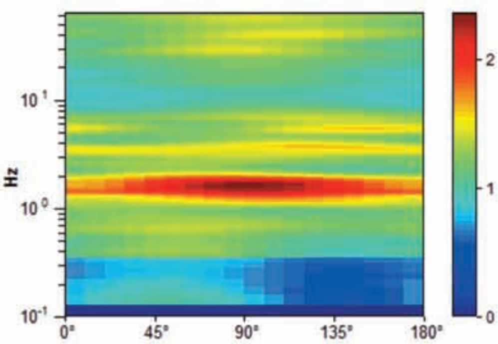
HORIZONTAL TO VERTICAL SPECTRAL RATIO



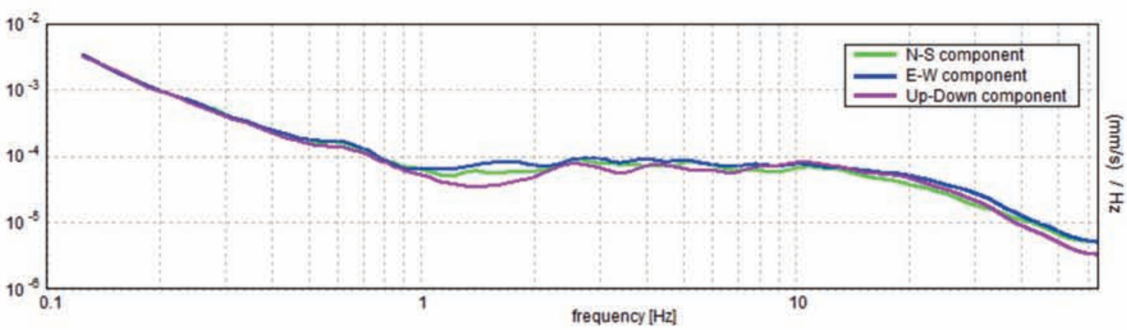
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 1.41 ± 0.02 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	1.41 > 0.50	OK	
$n_c(f_0) > 200$	2503.1 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 68 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$			NO
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$			NO
$A_0 > 2$	2.02 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.00697| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.0098 < 0.14063	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.385 < 1.78	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

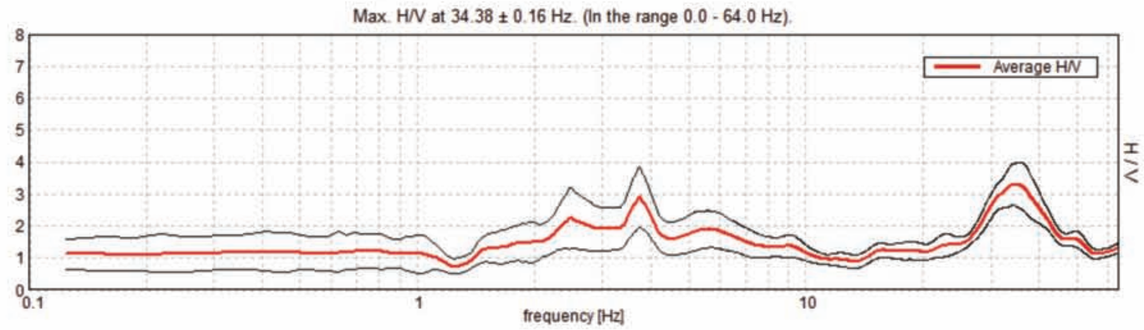
SEISMIC AMBIENT NOISE IN BERAT

AL01 – ALBANIA, BERAT

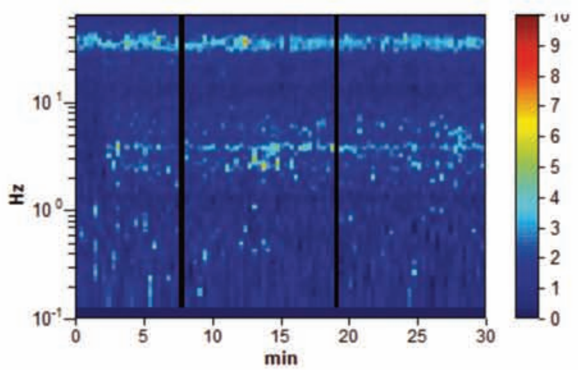
Instrument: TRZ-0005/01-09
Start recording: 19/11/11 16:26:20 End recording: 19/11/11 16:56:21
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30' 00". Analyzed 98% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

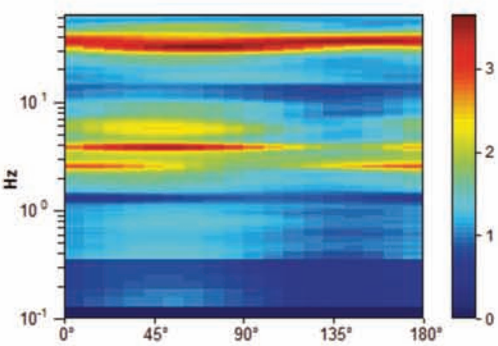
HORIZONTAL TO VERTICAL SPECTRAL RATIO



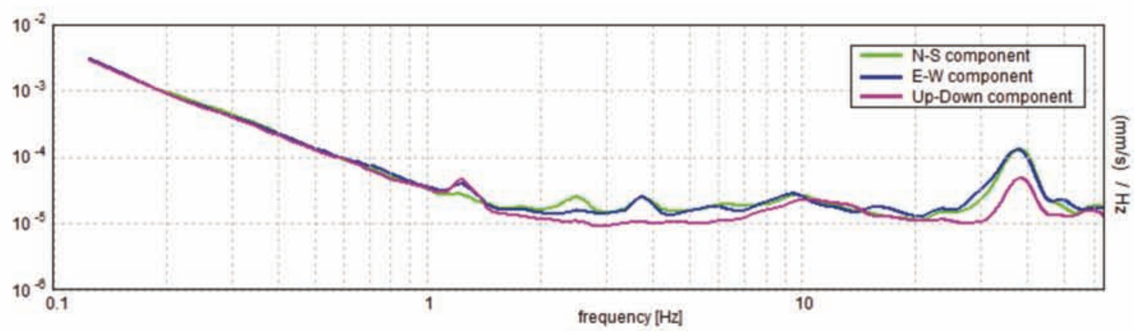
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 34.38 ± 0.16 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	34.38 > 0.50	**OK**	
$n_c(f_0) > 200$	60500.0 > 200	**OK**	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 1499 times	**OK**	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	26.625 Hz	**OK**	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	45.125 Hz	**OK**	
$A_0 > 2$	3.30 > 2	**OK**	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.0024| < 0.05	**OK**	
$\sigma_f < \varepsilon(f_0)$	0.08243 < 1.71875	**OK**	
$\sigma_A(f_0) < \theta(f_0)$	0.3253 < 1.58	**OK**	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

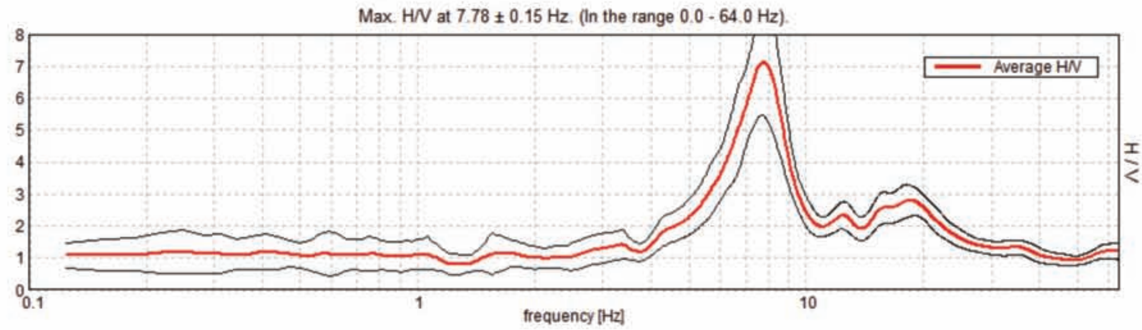
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL02 – ALBANIA, BERAT

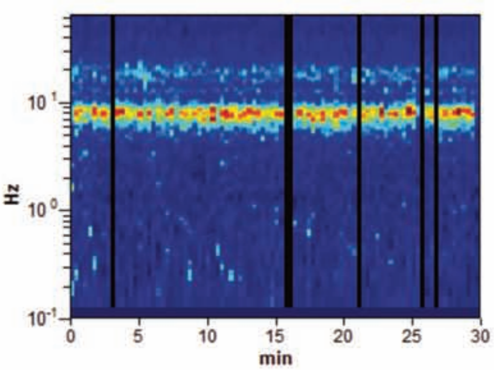
Instrument: TRZ-0005/01-09
Start recording: 19/11/11 17:49:35 End recording: 19/11/11 18:19:36
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30' 00''. Analyzed 93% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

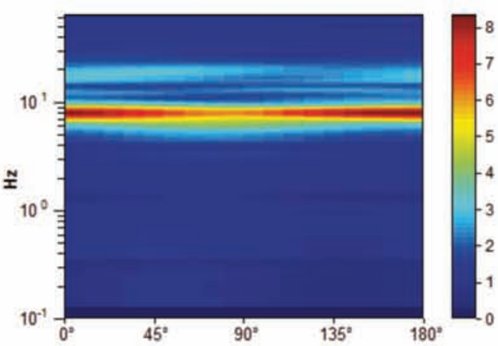
HORIZONTAL TO VERTICAL SPECTRAL RATIO



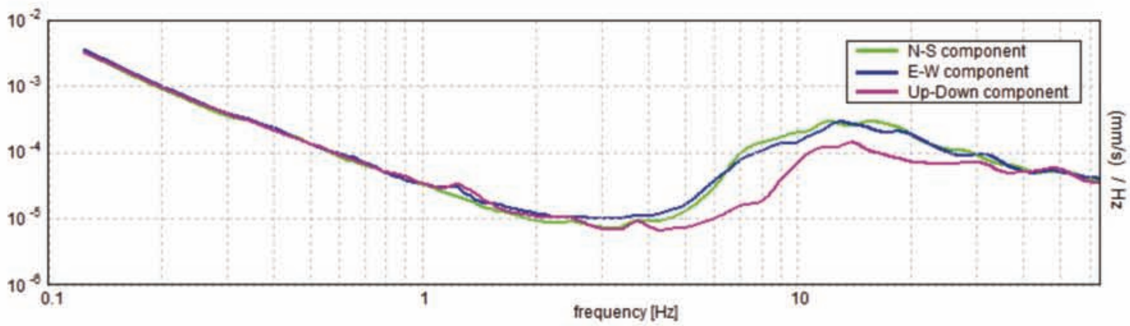
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 7.78 ± 0.15 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	7.78 > 0.50	**OK**	
$n_c(f_0) > 200$	13072.5 > 200	**OK**	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 374 times	**OK**	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0] \mid A_{H/V}(f^-) < A_0 / 2$	5.969 Hz	**OK**	
Exists f^+ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0 / 2$	9.281 Hz	**OK**	
$A_0 > 2$	7.14 > 2	**OK**	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.00962| < 0.05	**OK**	
$\sigma_f < \varepsilon(f_0)$	0.07489 < 0.38906	**OK**	
$\sigma_A(f_0) < \theta(f_0)$	0.8421 < 1.58	**OK**	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

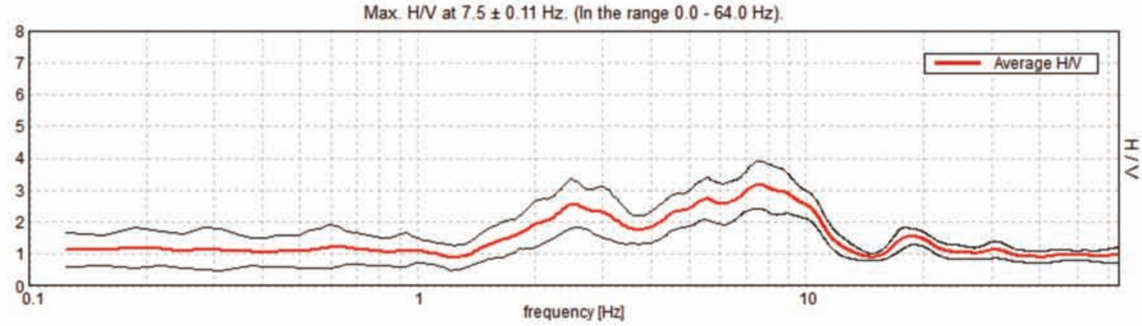
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	$0.25 f_0$	$0.2 f_0$	$0.15 f_0$	$0.10 f_0$	$0.05 f_0$
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL03 – ALBANIA, BERAT

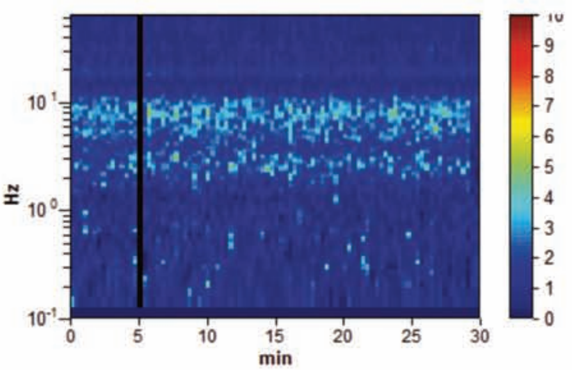
Instrument: TRZ-0005/01-09
Start recording: 19/11/11 18:37:58 End recording: 19/11/11 19:07:59
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30' 00''. Analyzed 99% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

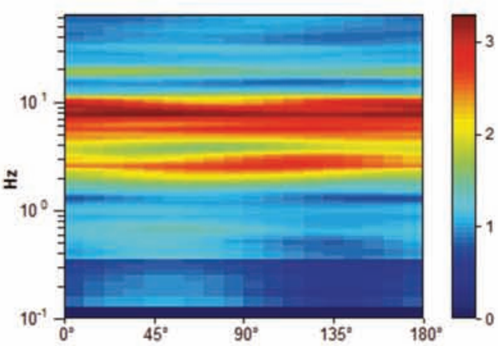
HORIZONTAL TO VERTICAL SPECTRAL RATIO



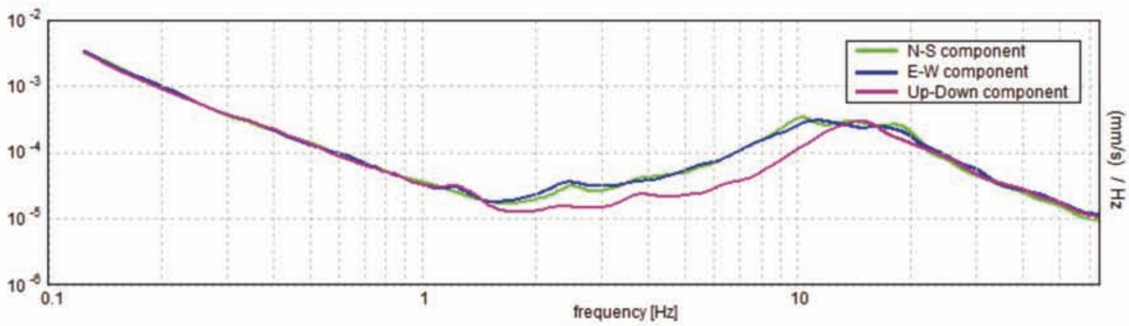
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 7.5 ± 0.11 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	7.50 > 0.50	OK	
$n_c(f_0) > 200$	13350.0 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5$Hz $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5$Hz	Exceeded 0 out of 361 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$			NO
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	11.531 Hz	OK	
$A_0 > 2$	3.17 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.00732| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.05491 < 0.375	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.3741 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

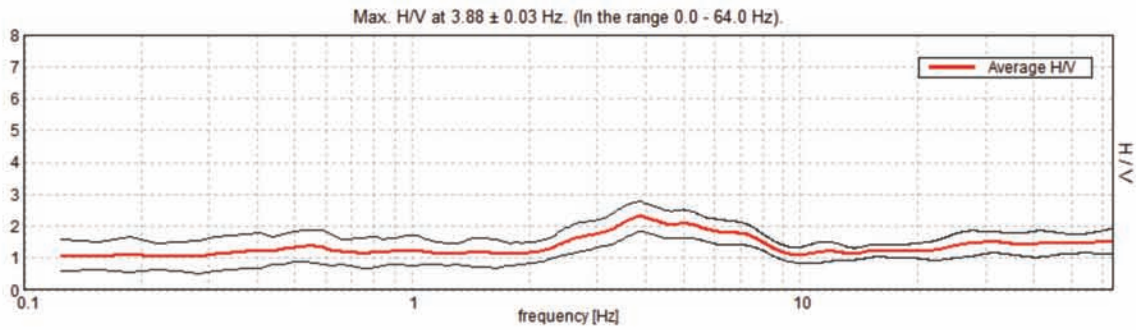
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL19 – ALBANIA, BERAT

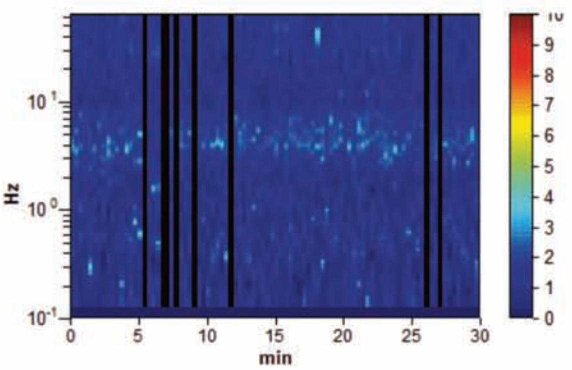
Instrument: TRZ-0005/01-09
Start recording: 23/11/11 17:57:12 End recording: 23/11/11 18:27:13
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30 '00''. Analyzed 91% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 15%

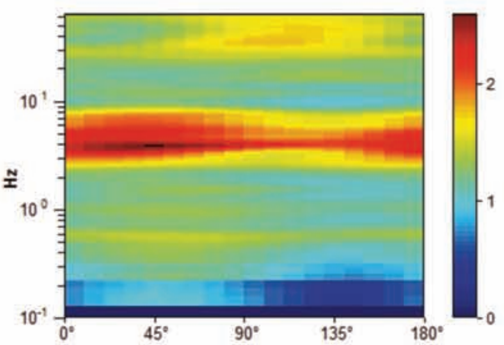
HORIZONTAL TO VERTICAL SPECTRAL RATIO



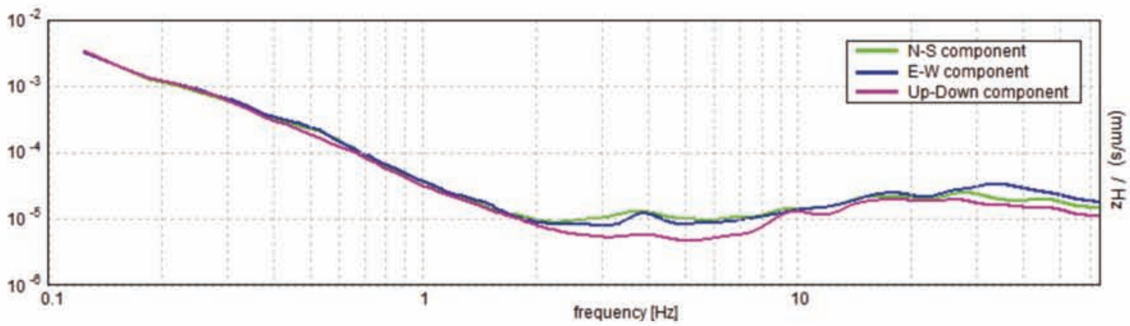
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 3.88 ± 0.03 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	3.88 > 0.50	OK	
$n_c(f_0) > 200$	6355.0 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 187 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	1.969 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	9.125 Hz	OK	
$A_0 > 2$	2.31 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.00377| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.01461 < 0.19375	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.234 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

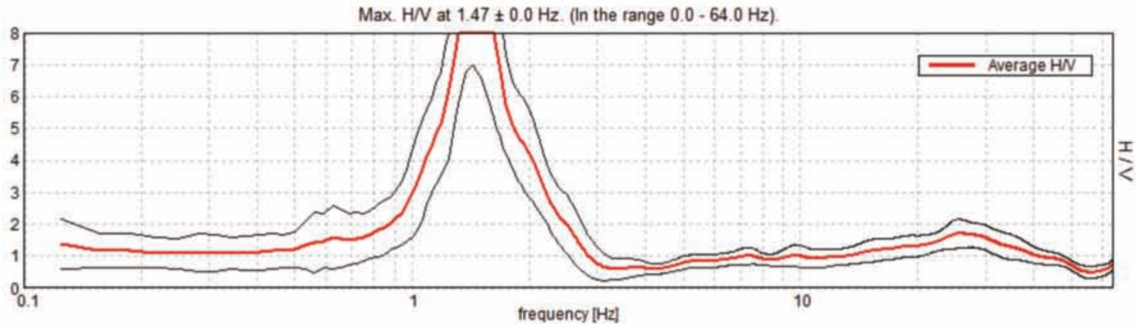
SEISMIC AMBIENT NOISE IN BUTRINT

AL07 – ALBANIA, BUTRINT

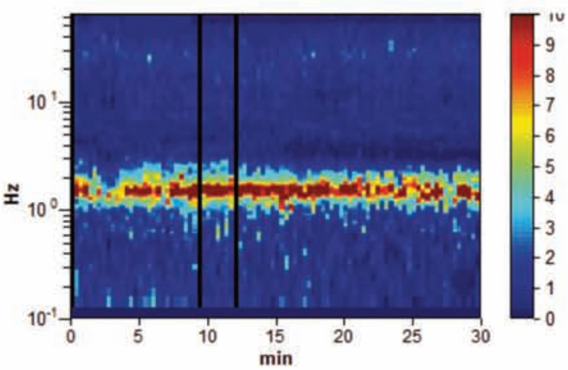
Instrument: TRZ-0005/01-09
Start recording: 21/11/11 11:39:40 End recording: 21/11/11 12:09:41
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30' 00''. Analyzed 97% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

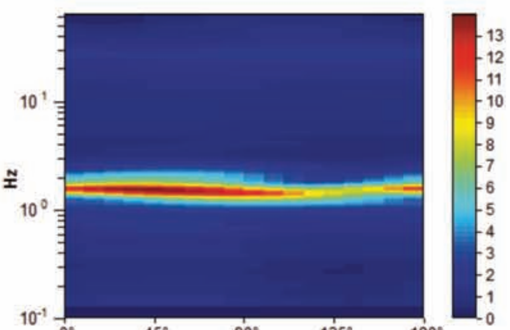
HORIZONTAL TO VERTICAL SPECTRAL RATIO



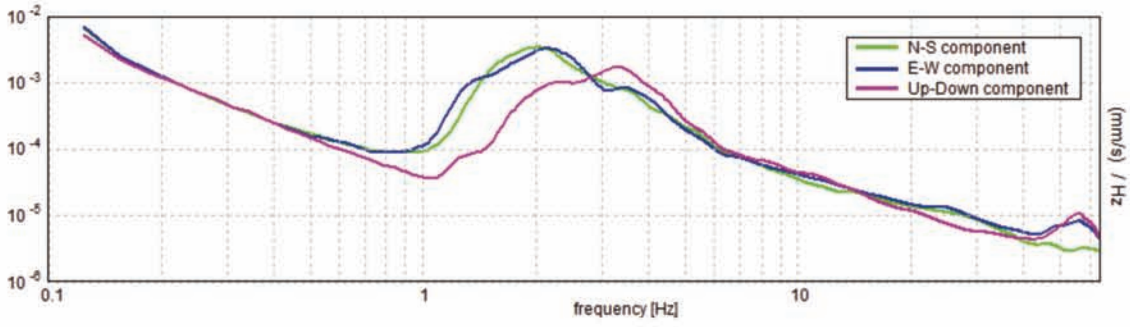
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 1.47 ± 0.0 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	1.47 > 0.50	OK	
$n_c(f_0) > 200$	2555.6 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 15 out of 72 times		NO
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0] \mid A_{H/V}(f^-) < A_0 / 2$	1.219 Hz	OK	
Exists f^+ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0 / 2$	1.75 Hz	OK	
$A_0 > 2$	11.64 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.00136| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.002 < 0.14688	OK	
$\sigma_A(f_0) < \theta(f_0)$	2.425 < 1.78		NO

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

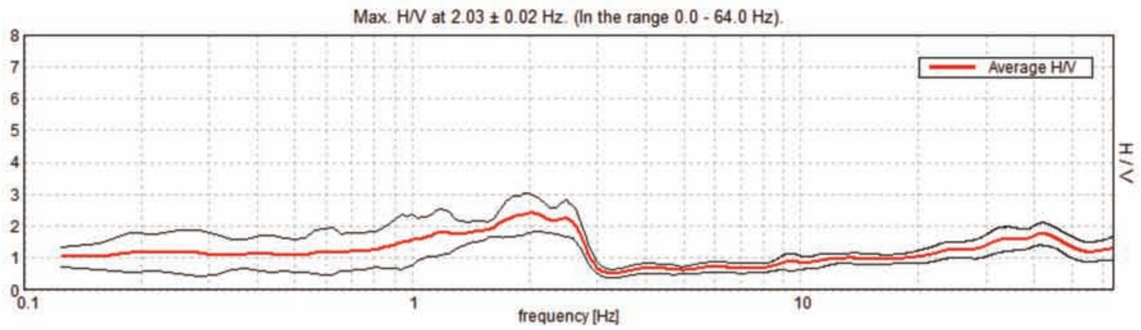
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL08 – ALBANIA, BUTRINT

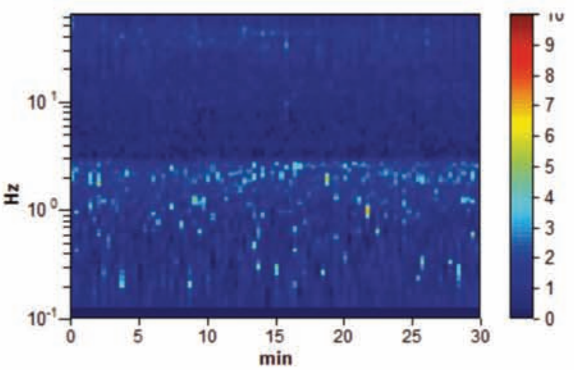
Instrument: TRZ-0005/01-09
Start recording: 21/11/11 12:40:07 End recording: 21/11/11 13:10:08
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30' 00''. Analysis performed on the entire trace.
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

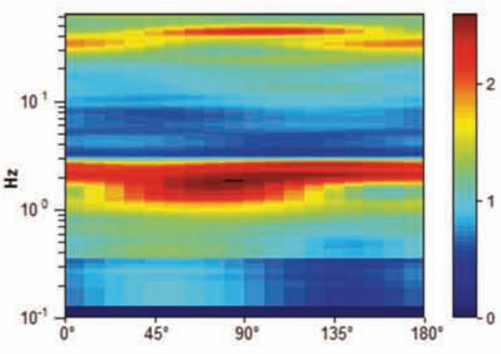
HORIZONTAL TO VERTICAL SPECTRAL RATIO



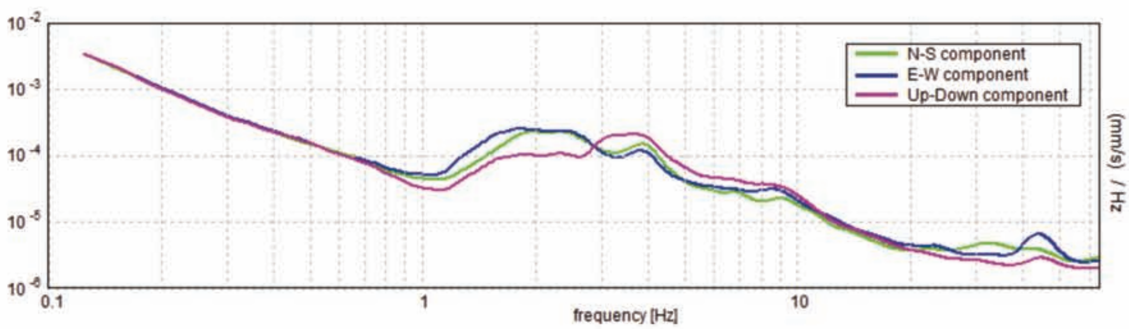
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 2.03 ± 0.02 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	2.03 > 0.50	OK	
$n_c(f_0) > 200$	3656.3 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 98 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	0.688 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	2.844 Hz	OK	
$A_0 > 2$	2.41 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.00475| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.00965 < 0.10156	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.3012 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

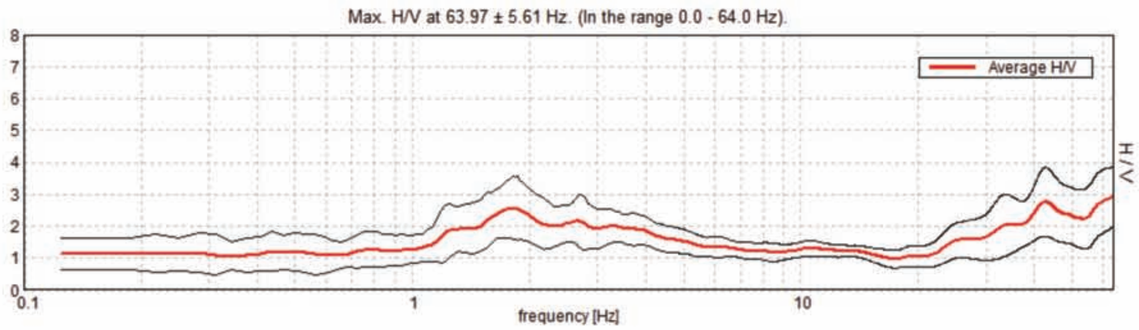
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL09 – ALBANIA, BUTRINT

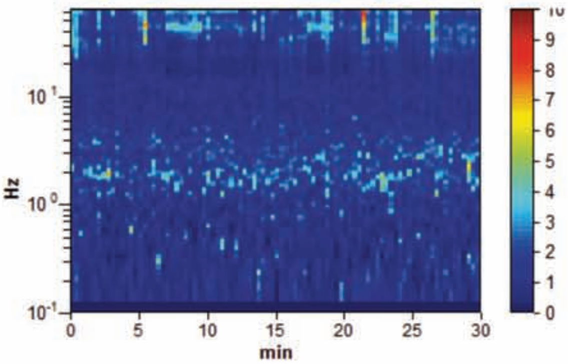
Instrument: TRZ-0005/01-09
Start recording: 21/11/11 13:35:40 End recording: 21/11/11 14:05:40
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30' 00''. Analysis performed on the entire trace.
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

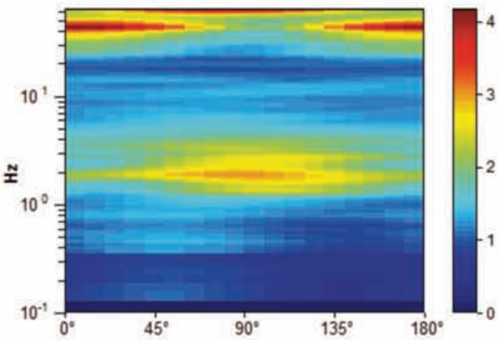
HORIZONTAL TO VERTICAL SPECTRAL RATIO



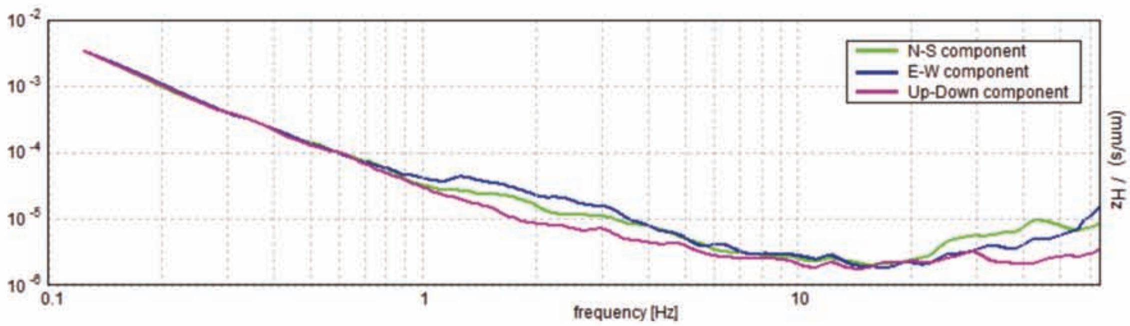
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 63.97 ± 5.61 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	63.97 > 0.50	OK	
$n_c(f_0) > 200$	115143.8 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 1026 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	24.188 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$			NO
$A_0 > 2$	2.92 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.04391| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	2.80873 < 3.19844	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.4699 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

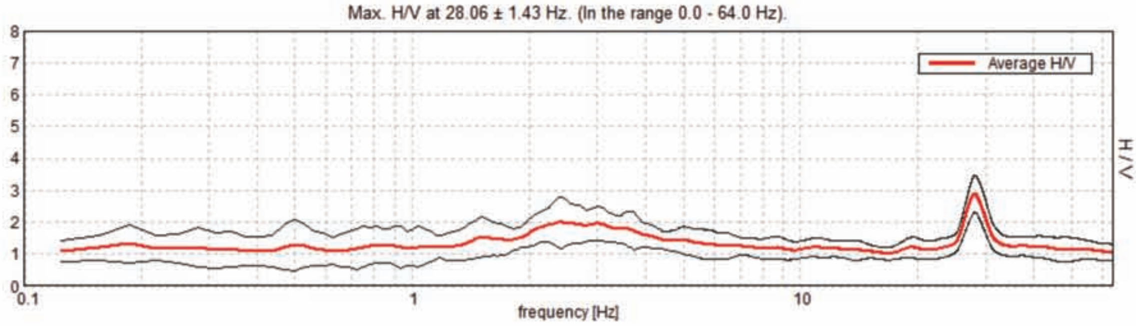
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL10 – ALBANIA, BUTRINT

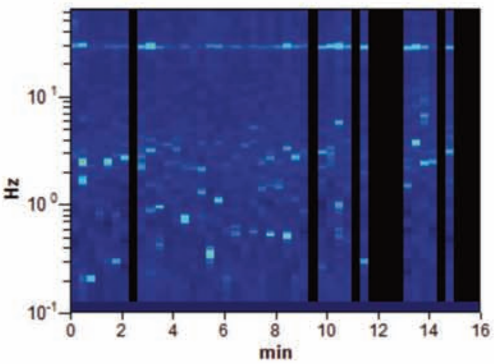
Instrument: TRZ-0005/01-09
Start recording: 21/11/11 14:21:33 End recording: 21/11/11 14:37:34
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 16' 00''. Analyzed 77% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

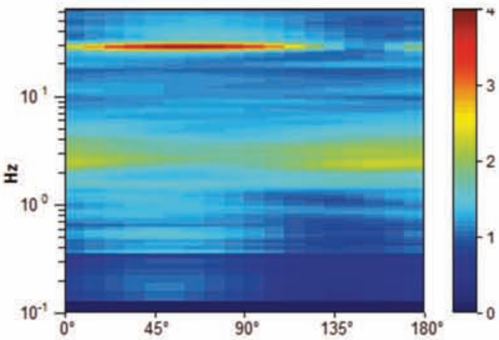
HORIZONTAL TO VERTICAL SPECTRAL RATIO



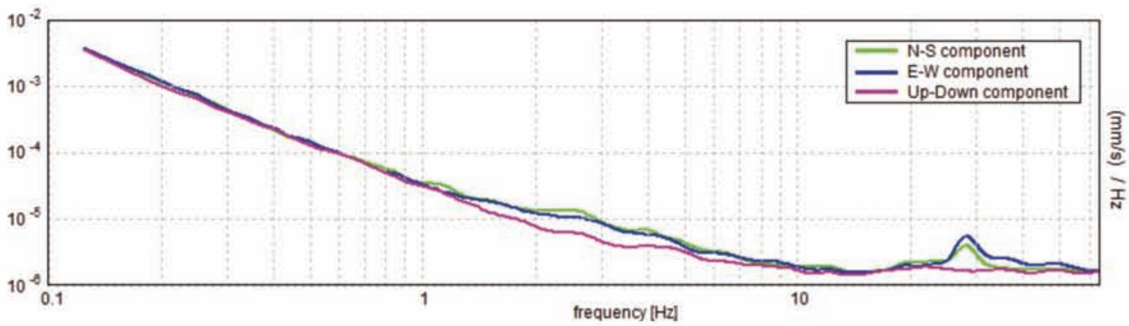
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 28.06 ± 1.43 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	28.06 > 0.50	OK	
$n_c(f_0) > 200$	20766.3 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 1348 times	OK	
Criteria for a clear H/V peak **[At least 5 out of 6 should be fulfilled]**			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	25.438 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	31.813 Hz	OK	
$A_0 > 2$	2.90 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.02477| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.69513 < 1.40313	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.2817 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

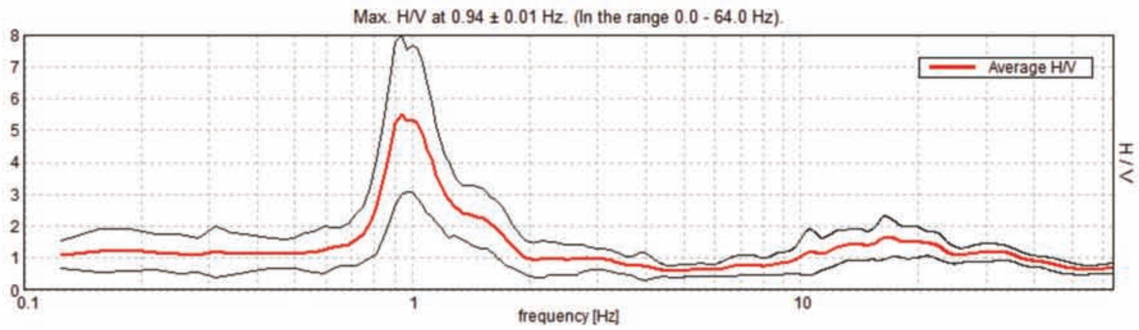
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL11 – ALBANIA, BUTRINT

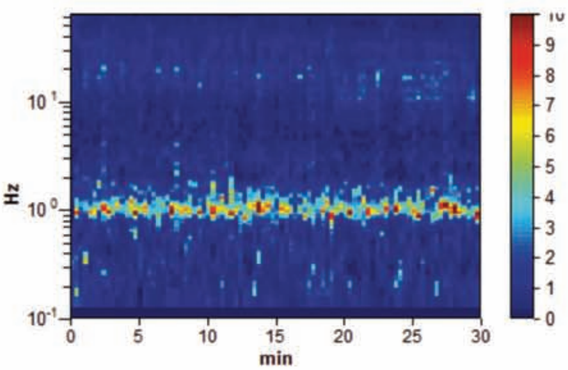
Strumento: TRZ-0005/01-09
Inizio registrazione: 21/11/11 15:20:00 Fine registrazione: 21/11/11 15:50:01
Nomi canali: NORTH SOUTH; EAST WEST; UP DOWN
Dato GPS non disponibile

Durata registrazione: 0h 30' 00''. Analisi effettuata sull'intera traccia.
Freq. campionamento: 128 Hz
Lunghezza finestre: 20 s
Tipo di lisciamento: Triangular window
Lisciamento: 10%

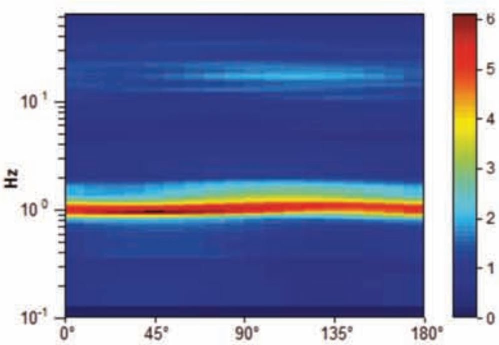
HORIZONTAL TO VERTICAL SPECTRAL RATIO



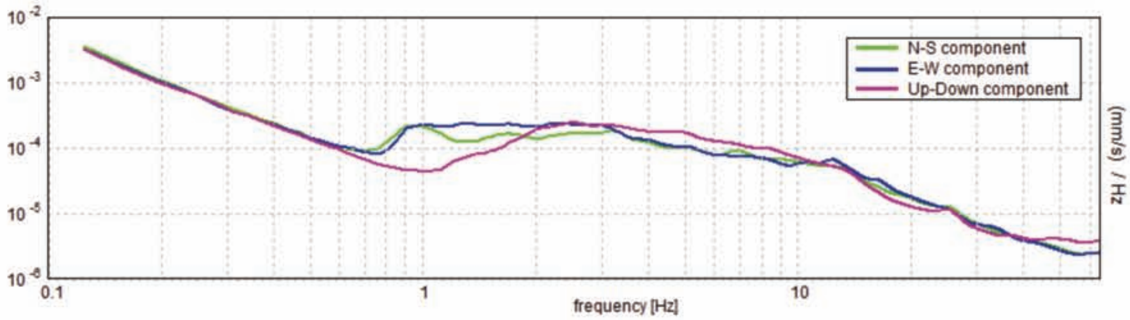
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Picco H/V a 0.94 ± 0.01 Hz (nell'intervallo 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.94 > 0.50	OK	
$n_c(f_0) > 200$	1687.5 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 8 out of 46 times		NO
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0] \mid A_{H/V}(f^-) < A_0 / 2$	0.813 Hz	OK	
Exists f^+ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0 / 2$	1.281 Hz	OK	
$A_0 > 2$	5.50 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.00743| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.00696 < 0.14063	OK	
$\sigma_A(f_0) < \theta(f_0)$	1.2636 < 2.0	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

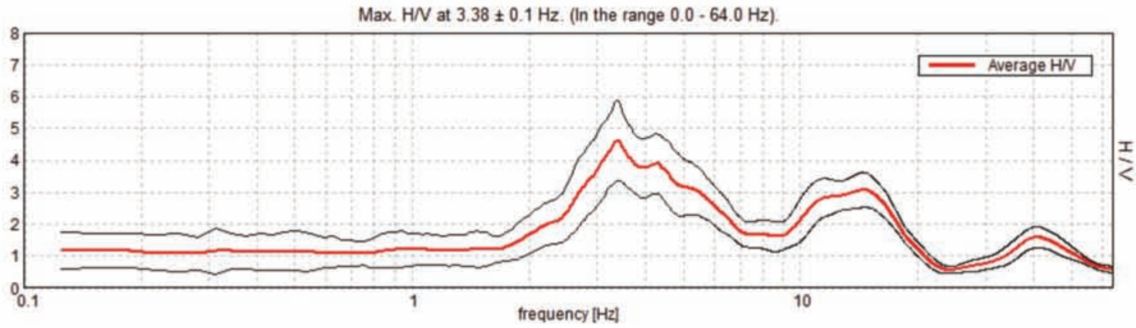
SEISMIC AMBIENT NOISE IN GJIROKASTRA

AL12 – ALBANIA, GJIROKASTRA

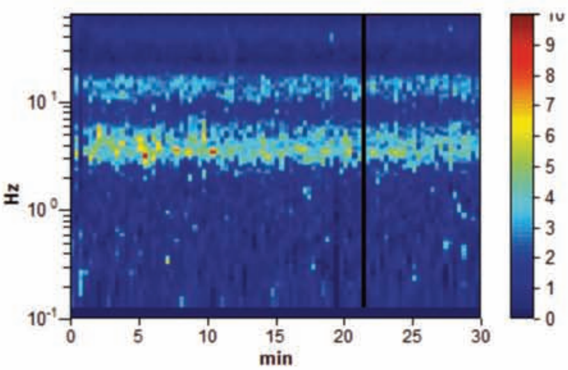
Instrument: TRZ-0005/01-09
Start recording: 22/11/11 10:12:57   End recording: 22/11/11 10:42:58
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h 30' 00''.   Analyzed 99% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

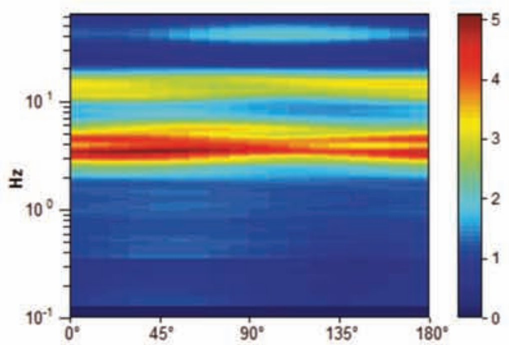
HORIZONTAL TO VERTICAL SPECTRAL RATIO



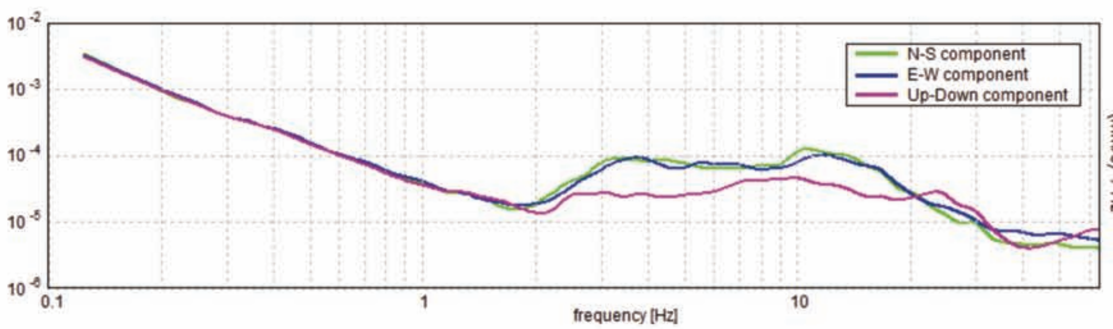
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 3.38 ± 0.1 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	3.38 > 0.50	OK	
$n_c(f_0) > 200$	6007.5 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 163 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0] \mid A_{H/V}(f^-) < A_0 / 2$	2.469 Hz	OK	
Exists f^+ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0 / 2$	6.375 Hz	OK	
$A_0 > 2$	4.62 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.01437| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.04849 < 0.16875	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.6346 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

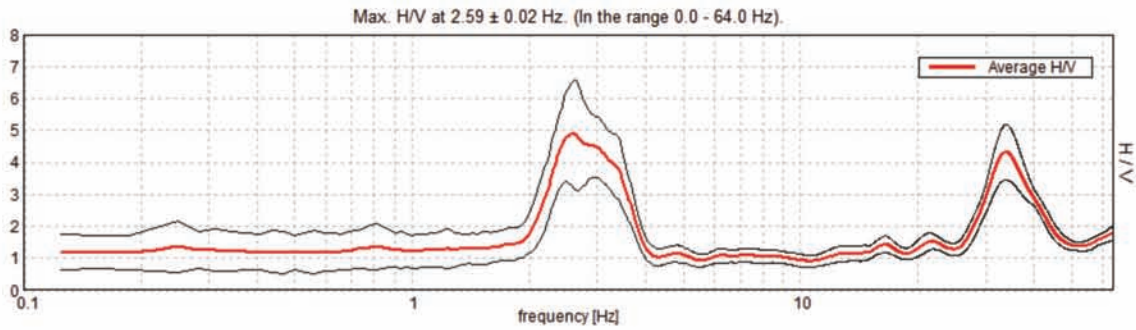
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL13 – ALBANIA, GIJROKASTRA

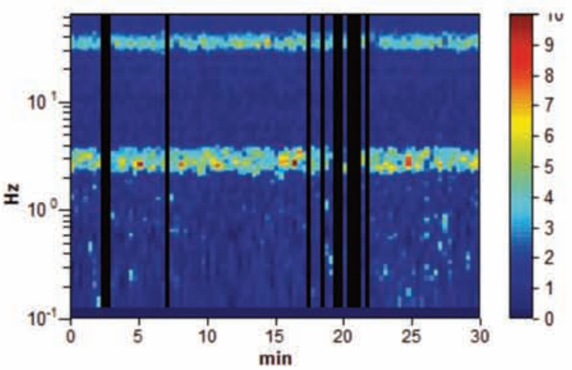
Instrument: TRZ-0005/01-09
Start recording: 22/11/11 11:34:24 End recording: 22/11/11 12:04:25
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h 30' 00". Analyzed 88% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

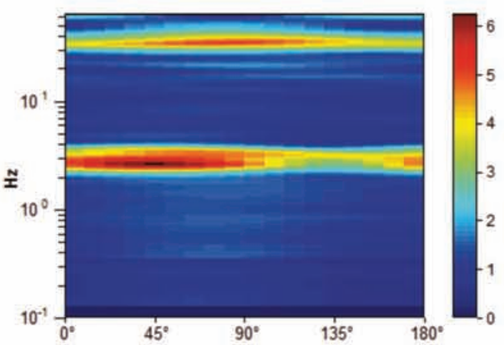
HORIZONTAL TO VERTICAL SPECTRAL RATIO



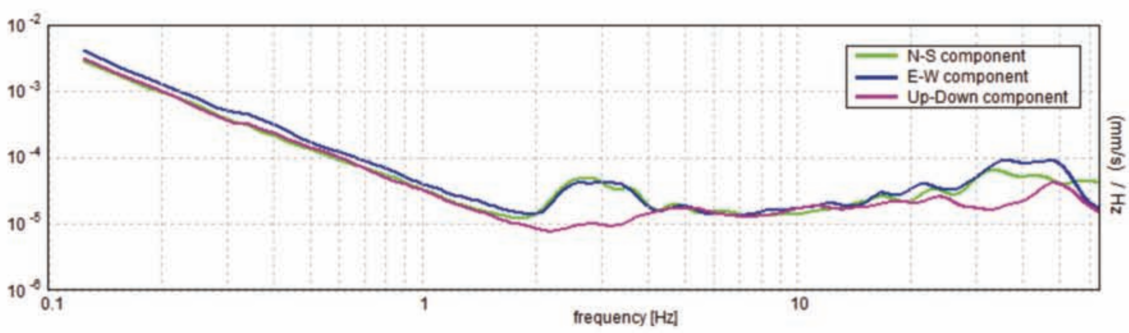
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 2.59 ± 0.02 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	2.59 > 0.50	OK	
$n_c(f_0) > 200$	4098.1 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 126 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0] \mid A_{H/V}(f^-) < A_0 / 2$	2.125 Hz	OK	
Exists f^+ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0 / 2$	3.719 Hz	OK	
$A_0 > 2$	4.88 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.00383| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.00994 < 0.12969	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.8215 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

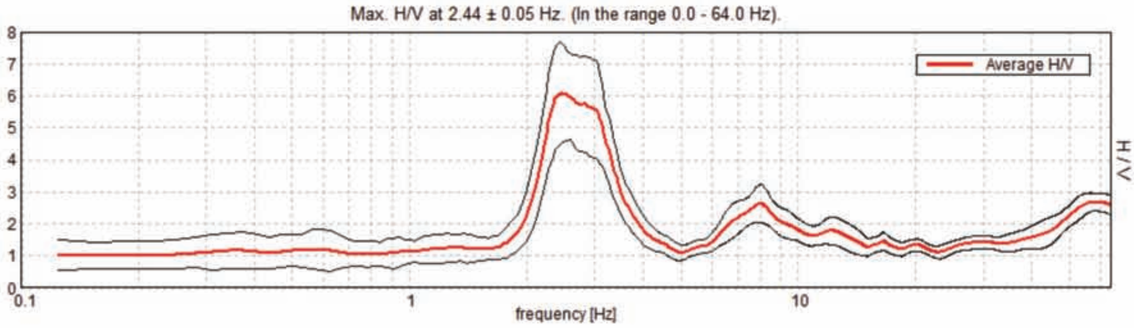
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL14 – ALBANIA, GJIROKASTRA

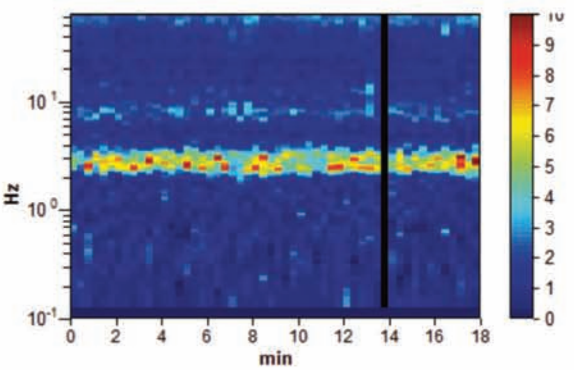
Instrument: TRZ-0005/01-09
Start recording: 22/11/11 12:11:59 End recording: 22/11/11 12:30:00
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h 18' 00''. Analyzed 98% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

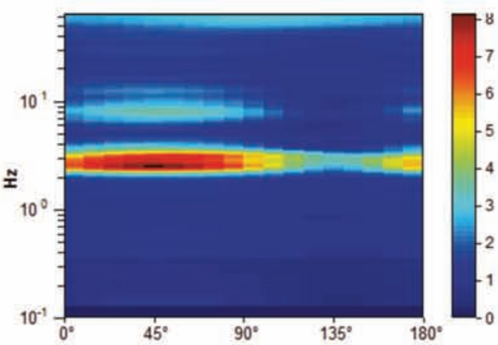
HORIZONTAL TO VERTICAL SPECTRAL RATIO



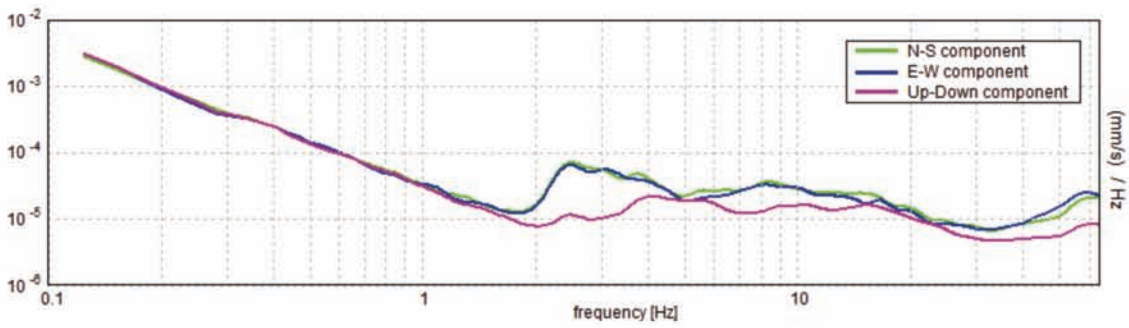
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 2.44 ± 0.05 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	2.44 > 0.50	OK	
$n_c(f_0) > 200$	2583.8 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 118 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	2.094 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	3.5 Hz	OK	
$A_0 > 2$	6.08 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.01002| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.02443 < 0.12188	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.7999 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

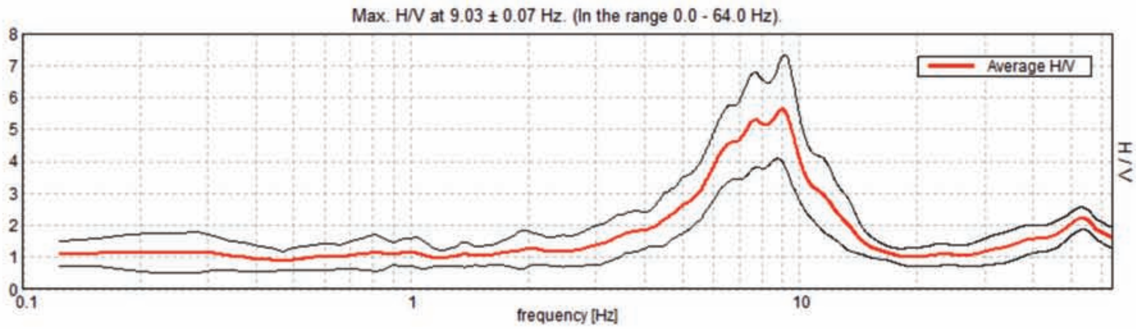
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL15 – ALBANIA, GJIROKASTRA

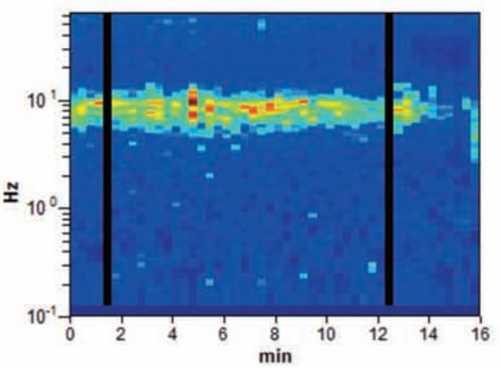
Instrument: TRZ-0005/01-09
Start recording: 22/11/11 16:00:40 End recording: 22/11/11 16:16:41
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h 16' 00". Analyzed 96% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

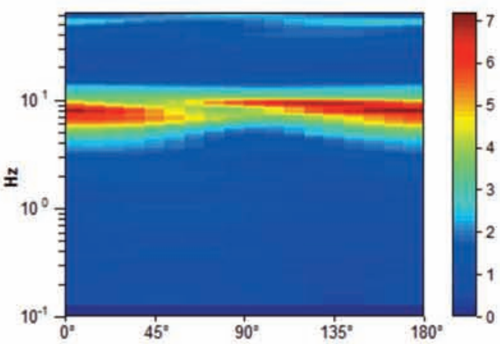
HORIZONTAL TO VERTICAL SPECTRAL RATIO



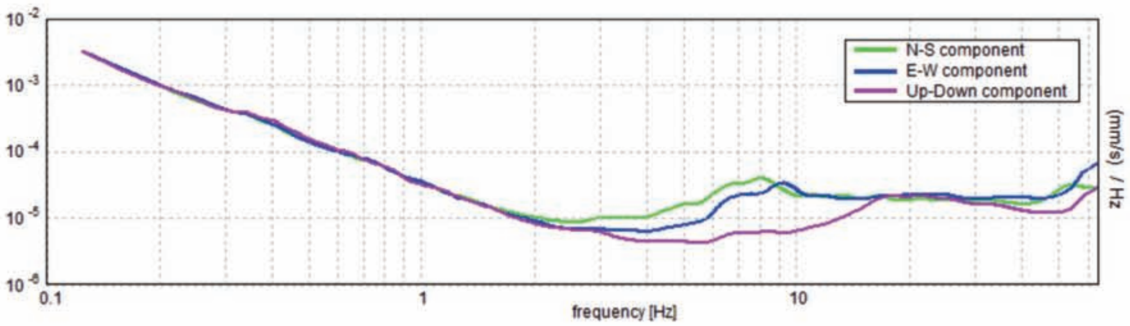
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 9.03 ± 0.07 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	9.03 > 0.50	OK	
$n_c(f_0) > 200$	8308.8 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 434 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	5.281 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	11.813 Hz	OK	
$A_0 > 2$	5.64 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.00354| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.03197 < 0.45156	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.8092 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

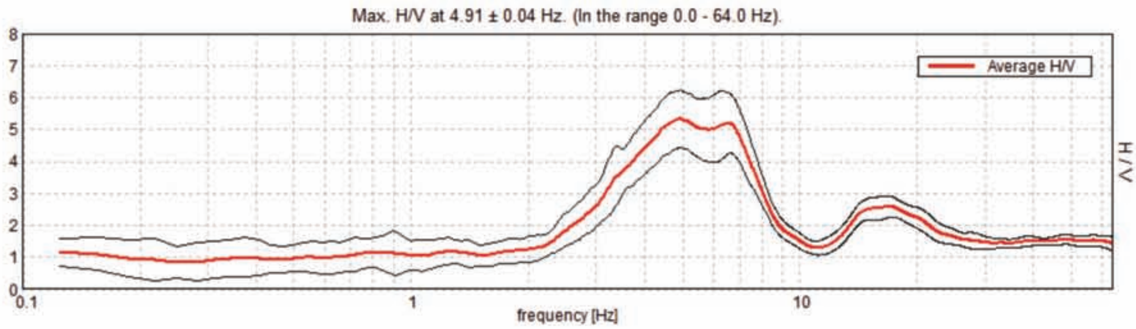
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL16 – ALBANIA, GJIROKASTRA

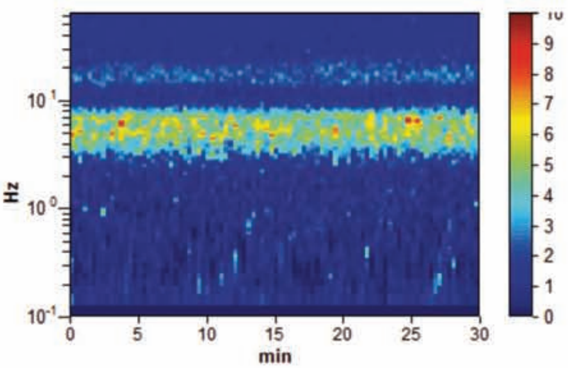
Instrument: TRZ-0005/01-09
Start recording: 23/11/11 10:22:28 End recording: 23/11/11 10:52:29
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30' 00". Analysis performed on the entire trace.
Sampling rate: 128 Hz
Window size: 20 s
Smoothing type: Triangular window
Smoothing: 10%

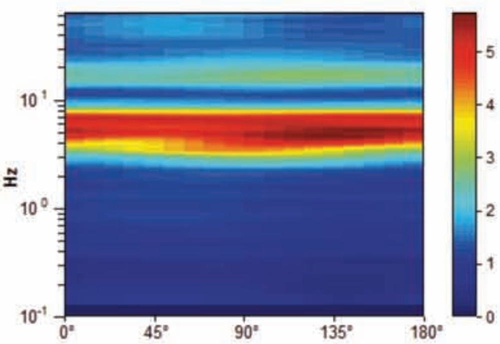
HORIZONTAL TO VERTICAL SPECTRAL RATIO



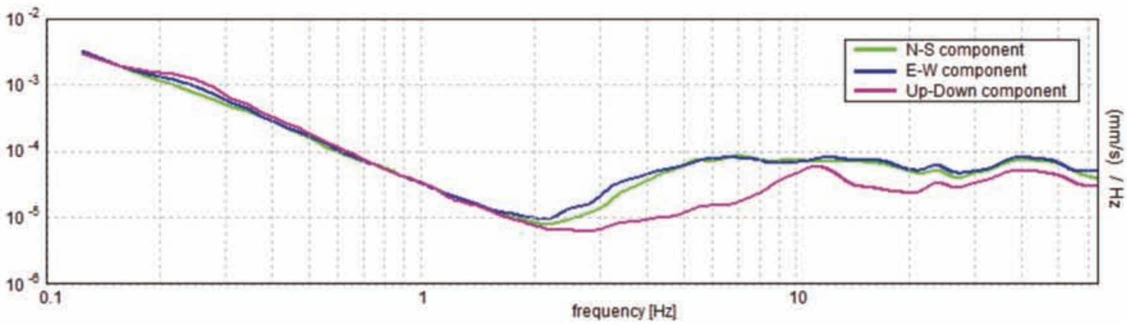
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 4.91 ± 0.04 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	4.91 > 0.50	OK	
$n_c(f_0) > 200$	8831.3 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 236 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	3.0 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	8.281 Hz	OK	
$A_0 > 2$	5.33 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.00449| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.02201 < 0.24531	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.4506 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

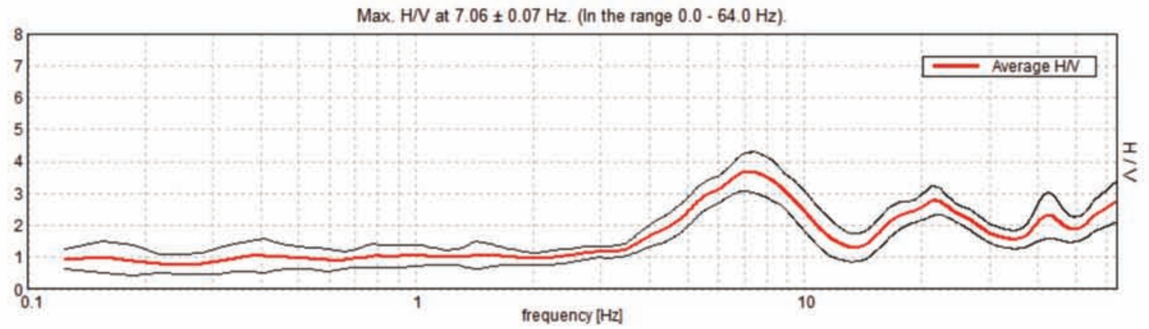
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL17 – ALBANIA, GJIROKASTRA

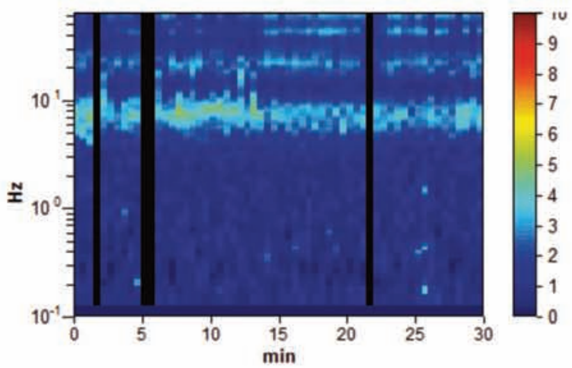
Instrument: TRZ-0005/01-09
Start recording: 23/11/11 11:25:33 End recording: 23/11/11 11:55:34
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30' 00". Analyzed 93% trace (manual window selection)
Sampling rate: 128 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 15%

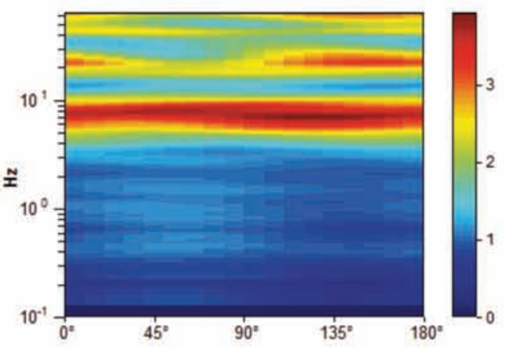
HORIZONTAL TO VERTICAL SPECTRAL RATIO



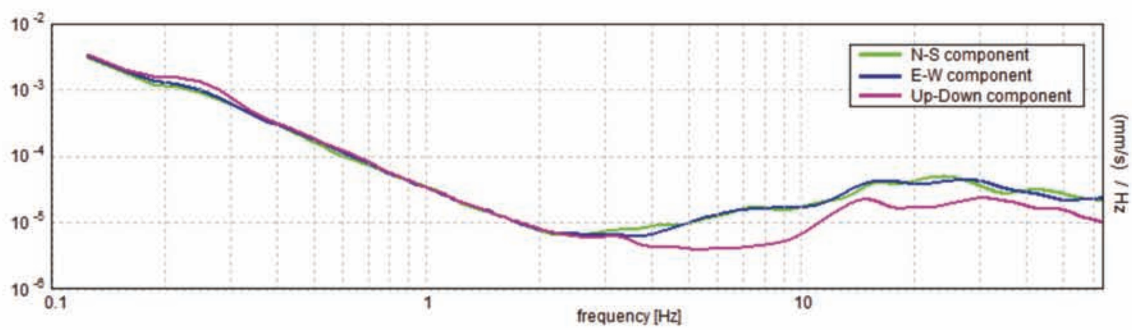
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 7.06 ± 0.07 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	$7.06 > 0.33$	OK	
$n_c(f_0) > 200$	$11865.0 > 200$	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 340 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	4.25 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	11.125 Hz	OK	
$A_0 > 2$	$3.67 > 2$	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	$\|0.0049\| < 0.05$	OK	
$\sigma_f < \varepsilon(f_0)$	$0.03457 < 0.35313$	OK	
$\sigma_A(f_0) < \theta(f_0)$	$0.2966 < 1.58$	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

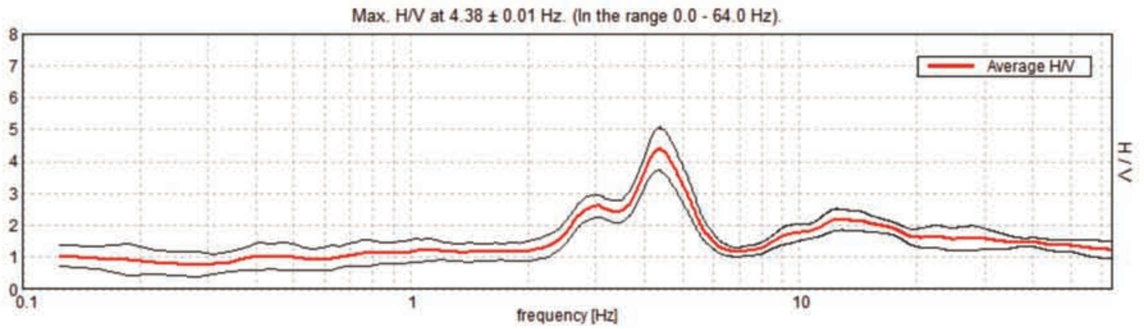
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

AL18 – ALBANIA, GJIROKASTRA

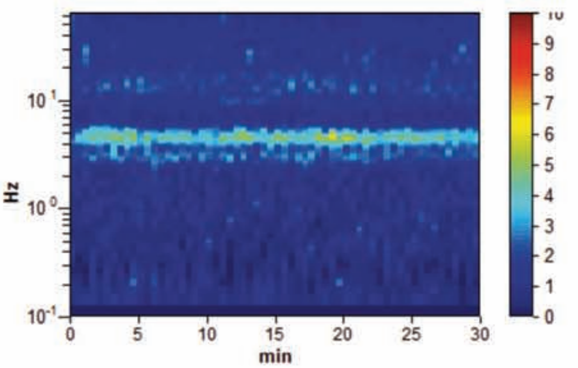
Instrument: TRZ-0005/01-09
Start recording: 23/11/11 13:01:54 End recording: 23/11/11 13:31:55
Channel labels: NORTH SOUTH; EAST WEST; UP DOWN
GPS data not available

Trace length: 0h 30' 00". Analysis performed on the entire trace.
Sampling rate: 128 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 15%

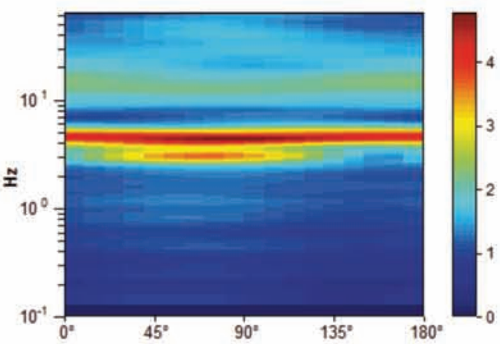
HORIZONTAL TO VERTICAL SPECTRAL RATIO



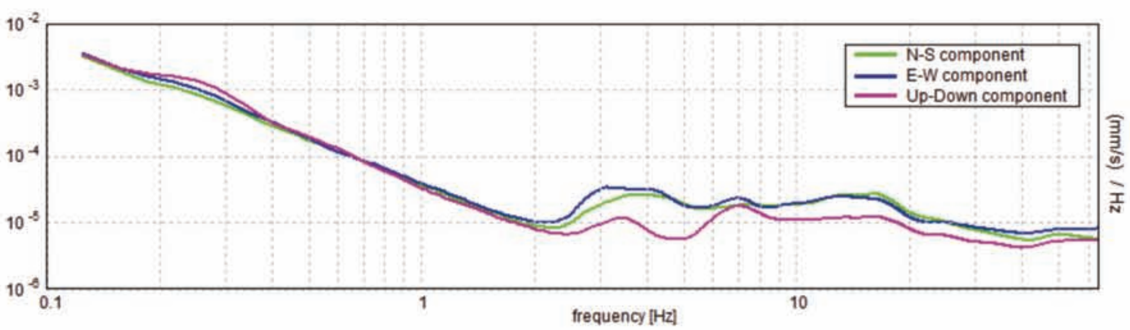
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 4.38 ± 0.01 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	4.38 > 0.33	OK	
$n_c(f_0) > 200$	7875.0 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 211 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	2.656 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	5.5 Hz	OK	
$A_0 > 2$	4.40 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.00139| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.0061 < 0.21875	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.3391 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

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Front cover
Butrint, Theatre

Back cover
Upper left - Apollonia, Bouleterion Temple
Middle - Berat
Lower right - Gjirokastra

The international debate concerning the overall capacity in disaster risks mitigation and adaptation strategies of entire systems, communities and sites has increased significantly during the last decade, mainly due to the interplay of multiple factors which have worsened the severity of hazards turning them with increased occurrences into full-fledged disasters. Nowadays, an integrated approach is mandatory in the field of sustainable development and Disaster Risk Reduction (DRR): the traditional rift between culture and science, and the subdivisions among disciplines and fields of science have to be overpassed by the needs of our times. These compel us to interface the advancements in science and technology in DRR with policy makers, emergency responders and local communities. Working in synergy in an integrated manner is not an easy task to undertake. CNR-IGAG, the UNESCO Regional Bureau for Science and Culture in Europe and ICCROM, under the framework of the ONE UN initiative, have endeavored to make this idea a working concept: scientific field assessment of geo-vulnerabilities in the World Heritage Sites of Albania have been combined with the sucessful attempt to train emergency responders and site managers to deal with DRR in the same sites. The achievements of such activities constitute the narrative of this script.

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