

Historical Disasters Data Extraction and a Modern Marine Geohazards Early Warning System in the Area of the North Bulgarian Black Sea Coast

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Keywords: Historical Disasters – Earthquakes And Tsunamis, Modern Early Warning Systems

SUMMARY

The recent disasters happens almost everyday in the World. The increased access to the information due to the very active modern information channels provides updated data and description of consequences. Several dramatic destructive events with large negative effects to the society and infrastructure (for example - the huge tsunami near Sumatra in 2004 and the earthquake and tsunami in Japan 11 March, 2011) generated losses for billions of dollars. To avoid such negative effects the modern technology of the early warning systems has been developed by the advanced countries (such as Japan, USA and some others). On the other side most of these mega events did not appear earlier (or have been forgotten). The recent natural science use all advanced technologies to fill the gap in the data for past historical disasters events. In Bulgaria such investigations started during the last years and bring new and reliable information. The major role in this process plays the GPS technology together with other modern geodetic measurements. In this research such data are displayed related to two very important historical disaster events – The Cybele temple destruction in 554 and the bastion destructions in Provadia dated about 6 500 years BP. Both major destructive complex events are due to the strong earthquakes generated most probably by the Shabla-Kaliakra seismic zone and evidence of generated tsunami have been proved for the 554AD event. Both cases are used as referent events and play important role to the establishments of a modern early warning system for marine geohazards. All the data and results are described in this paper.

SUMMARY

Геодезическите измервания играят важна роля при откриване на данни и извличане на информация за станали исторически опасни природни явления. В разработката се разглеждат два такива случая – разрушаването на храма на Кибела в Балчик от комплексно бедствено явление включващо земетресение, цунами и свлачище (около средата на шести век) и разрушаването на защитен бастион от силно земетресение (датирано преди около 6 500 години) в района на Солницата-Провадия. И двете събития са послужили като референтни явления при проектирането на модерна система за предупреждение от морски опасности в северната част на Черно море, изградена по линия на двустранно сътрудничество с Румъния. Така разработката хвърля мост между историята и съвременните геодезически технологии.

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1. INTRODUCTION

The newly established discipline called Archaeoseismology is among the advanced techniques working towards the identification of ancient earthquakes. In the last few years specific targeted investigations were conducted in Bulgaria in order to recognize ancient strong earthquakes and their effects to the archaeological sites that had brought to light many new and unexpected findings. Two main historical disastrous events are under investigations: Solnicata (Provadia – NE Bulgaria) and the Cybele temple (Balchik – NE Bulgaria). Both events serve as referent cases for extraction of historical data about the influence of strong earthquakes and tsunamis. Both events have been considered to the newest technology of the early warning system developed for the marine hazards detection and early warning issue to the population and the decision makers.

2. TWO HISTORICAL HAZARDOUS EVENTS

2.1 Solnicata (Provadia)

The Neolithic people have started to produce salt to meet their needs around 5400 BC at a place now called Provadia-Solnitsata. A large salt body rediscovered recently in 1917 served as a source for this prehistoric factory that produced the most valuable item in prehistory – the salt, the most important and vital product of the early farmers. This unique site in Europe was excavated by archaeologists (excavation started in 2005 and continues up to now) thus shedding light over the history of this place. A huge scale industry for this prehistoric period was developed that had functioned for more than 1000 years. Thick walled pots and hearths for brine evaporation have been intensively produced and can be seen now. After the rediscovery of the salt, new and more sophisticated techniques of salt production (the biggest raw material source for the nearby huge salt plant) have been applied since mid-1950s. A prehistoric earthquake that occurred about 6 500 years ago and destroyed the Chalcolithic dry-stone fortifications may be considered as a natural hazard interrupting the salt production for some time. There are many facts, evidences and a hypothesis about such an event that support this conjecture.

Field studies have been performed in November 2008 in order to investigate the observed facts from seismological point of view. Different structures were studied. The main features were the fallen large stones (dimensions between 1 and 0.5 m³) representing elements from two fortifications (twin towers or bastions) from the defense system of the settlement dated to the middle Chalcolithic (4600-4500 BC) and situated at the SE entrance.

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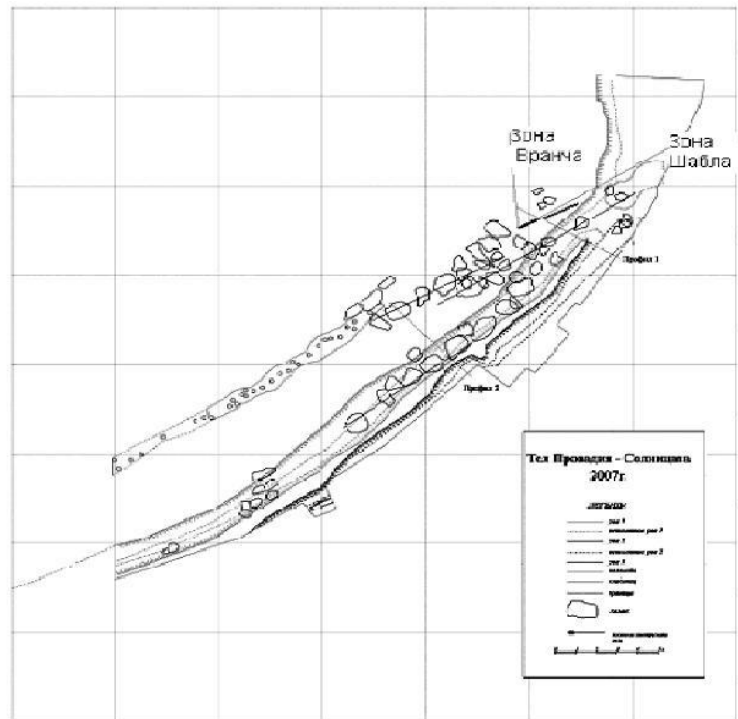


Fig. 1. Original plan of the fallen big stones and their location. The directions to the seismic sources of Vrancea and Shabla-Kaliakra zone are identified using GPS measurements, as well as the direction of the maximum seismic force – coming from the NE – are shown (Ranguelov, Nikolov 2008)

The stones (unprocessed breccia marbled limestone) from the lowest row of the SW bastion were found *in situ* as foundations. Same size stones (at least 22 and many smaller ones) were fallen down to the S-SW into the deeper swell and were dispersed at distance from two to eight meters. The *in situ* measurements by simple triangulation show the direction of the fallen stones to be 50-60° to the north (fig.1; Ranguelov et al. 2008.).

2.2 Cybele temple (Balchik)

Starting excavations in April 2007 the Cybele temple presents an extreme example of the relatively well documented complex disaster historical event influence, consisting by effects of earthquake, tsunami and landslides. All of these events influence simultaneously (and/or consecutively), destructing and preserving the remains of the temple. The 543 earthquake (the most probable reason of the temple's destruction), was mentioned by E.Guidoboni in the book – "The Mediterranean earthquakes" - as a possible generator of a local tsunami. The excavations discovered a low (down to the floor of the temple) small layer of burned material mixed with the sand and sea mollusks shells. In this layer as well as up, a lot of marble artifacts have been indicated. They are mixed and broken, together with the stable preserved parts of the marble chairs, fixed on the floor. A broken marble plate with written names of the

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sponsors of the ancient temple was discovered. After the reconstruction all parts of this plate have been puzzled, which shows that the plate was broken on the floor and no parts extracted afterwards. This means that the broken process occurred due to the falling down of the plate parts during the earthquake. Then the parts have been mixed most probably due to the sliding inside masses. The preservation of the walls to the certain height means that these walls have been buried by the surrounding masses.

Burned roof remaining is due to a powerful fire followed by the collapse due to the earthquake, which destroyed the bigger part of the temple (cracks and slightly moved visible elements on the walls and the floor) and the inside located marble elements – plates, statues, etc. – some of them broken due to the fall down process. Then tsunami, which brought sand and mollusks shells and after all landslides (at once or several times), which filled the space into the destructed temple, mixed some artifacts and buried the remains of the temple. This can explain the observed fact, why the rest of the walls are untouched up to a certain level. This very clear interpretation shows how much information could be retrieved by ruins in case of well preserved archeological sites.

The ancient chronics by Demetrius Calatius, Strabo, etc. outlined that strong earthquake accompanied by huge soil masses slides and possible generated tsunami flooded the ancient Greece colony Bisone in 3rd century BC. This leads to the movement of the port-city, located near shore to the up hills position and a new development of the town. Probably the same occurred with Dionisopolis (Balchik) after the destructive 543 seismic event. This heavy disasters influence sometimes led to the movements of relatively large colonies (town and villages with their inhabitants). They had heavy and huge consequences to the ancient people, changing their style of everyday life and work.

Summary table about the two historical hazardous events under investigation:

Historical hazardous event	Archaeological site (location, age):	Observed effects	Extracted parameters of the destructive event:	Geodesy methods applied
Earthquake	Solnitsata – Provadia, 4550 years BC	Destructed bastions, fallen stones elongated position	Approximate intensity, magnitude, distance to the source, source location	GPS, land triangulation
Earthquake, tsunami, landslide	Cybele temple – Balchik, 3 rd c.BC-5 th c.AD	Cracked walls, broken artifacts (statues, plates with inscriptions, etc.), deposited sand and shells of mollusks	Approximate intensity, magnitude and source location	GPS, leveling

We used GPS measurements to document the recent position of the ruins and all artifacts. The additional leveling measurements prove that the present level of the floor of the temple is over the recent sea level on exactly 4.15 cm. Following the fact that a sand layer was deposited with an approximate thickness of about 3-4 cm and considering the content of the broken shells of mollusks in it, we conclude that this layer was deposited by a tsunami, most probably generated by the same seismic event. This new discovery brings new and unknown information about a complex destructive event followed by landslide activation. Thus the ruins have been preserved.

3. THE EARLY WARNING SYSTEM ABOUT MARINE GEOHAZARDS

Operational joint early-warning system to marine geological hazards of risk has been created for the Ro-Bg Black Sea cross-border area, comprising of following modules: network of complex, automatic marine measurement equipment (total no. of 5 gauges) installed in key points of the Black Sea deep bottom area. Regional capability for marine seismic monitoring and surveillance. network of on-line stations for geodynamic surveillance of the Black Sea cross-border area state-of-the-art computing capabilities interconnecting the seismic and marine data - from Romania (Constanta – GeoEcoMar and Eforie Nord - NIEP) and Bulgaria (Varna-IO-BAS and Russe - GI-BAS)

The modeling (Ranguelov, 2010) of the travel times using most conservative model shows that the time interval that tsunami can reach the coast is between 20 and 40 minutes. This time is very limited to any safety measures. Thus is shown that the intended TEWS in the black sea (Romania-Bulgaria border region) is really time deficit system.

To create the correct pre-calculated kinematics models, the virtual (closer to the reality) seismic sources, with their respective parameters have been selected (Ranguelov, 2011). The travel time of a tsunami front is between 20 and 30 minutes to the nearest sea coast.

During the efforts to make such a system operational in a real time mode special investigations were performed to establish a Decision Matrix (DM) before warning issue. – Figure 2. The main focus of this research was to incorporate all the available equipment deployed on land and in the sea. The main hardware components included in the system are as follows (Ranguelov, 2014):

- SMD – strong motion devices (detect strong motions generated by earthquake)
- SMD and local and regional seismic networks (BG,ROM) (provide automatic earthquake parameters determination (in 5-10 min – corrected by the staff)
- Complex Bottom Stations (CBS=OBS+DART) (detecting the tsunami generation)
- GPS networks: Bulgaria (5 stations), Romania (13 stations);
- EXT – Extensometers networks (Bulgaria local network)
- The data centers – Varna and Constanta (selected the most reliable earthquake and tsunami scenarios).

Algorithm table for the early warning issue

Detection	Confirmation	Data center activity	Next step	Warning issue (operational part)	Next processing (research part)
Seismic signals: Strong motion devices (SMD) threshold over a fixed value (Y/N)	OBS	Activated	Scenario selection based on the earthquake information determination	Yes - According to the Decision Matrix (based on the scenario selected)-	N
	Y	Activated			
	N	Activated	Step ahead	No - Step ahead	Y
Tsunami generated – water level changes (Y/N)	Bottom pressure gougues: Y	Activated	Scenario selection based on the pre-computed scenarios	Yes – According to the Decision Matrix (based on the scenario selected)	Y
		Activated	Step ahead	No- Step ahead	Y
GPS surface displacements over a threshold (Y/N)	Y	Activated	Step ahead	Yes- According to the Decision Matrix.(WI)	Y
	N	Activated	Next step	No- Step ahead	Y
EXT displacements on active faulsts, landslides and movable soils (Y/N)	Y	Activated	Step ahead	Yes- According to the Decision Matrix. WI	Y
	N	Activated	Next step	N - Step ahead	Y

After the algorithm was created three levels of alert of the tsunami warning issue has been introduced (Figure 2). They are consistent with the threshold levels for any of the used equipment. The complex assessment needs the logic tree development using the convolution of all the devices detected signals. To put the threshold near to the reality values all information about the recent and historical events has been implemented. Local seismogenic and tsunamigenic conditions are considered about the combination of the seismic and tsunami warnings (Ranguelov, 2011):

- a) in general shallow earthquakes with magnitudes reaching Ms7-7.5 (for example 3rd century BC, 543AD, 1444, 1901 seismic events), are potential generators of tsunamis.
- b) historical data and descriptions about the tsunami observations (for example 3rd BC, 543AD and 1901 tsunamis) (Ranguelov et al., 2006).
- c) recent nonseismic tsunami event (for example 7th May, 2007) (Ranguelov, 2011).

SMD	CBS	GPS	EXT	Tsun warning	
Green	green	green	red	green	green
Orange	green	green	red	green	green
Red	green	green	red	green	orange
Green	orange	green	red	green	orange
Orange	orange	green	red	green	red
Red	orange	green	red	green	red
Green	red	green	red	green	red
Orange	red	red	green	red	red
Red	red	red	red	red	red

Figure 2. Decision Matrix for the tsunami warning issue – three levels of alert.

4. CONCLUSIONS

- Two important major seismic events have been used to extract useful and necessary data and used for the recent and modern early warning system about marine geohazards developed on the border region of Bulgaria and Romania.
- For operational purposes (as well as for the further research) special functionality algorithm has been implemented to include all available and active equipment.
- Unique decision matrix has been proposed for the effective and reliable warning issue to the decision makers, administration and population.
- Several problems exist for the warning dissemination due to the limited time, legislation issues and effective management of such a modern system.

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BIOGRAPHICAL NOTES

Boyko Ranguelov - born 07.07.1950 in Sofia, Bulgaria. Professor in Mining and Geology University. Conducted research in Geophysical Institute – Bulgarian Academy of Sciences. Visiting Scientist in the EC-DG Joint Research Centre (JRC) and Bologna University, Italy. UNESCO specialization in USGS, Menlo Park, California, USA. Active player in the UN International Decade of Disaster Reduction (IDRR) and the International Strategy of Disaster Reduction (ISDR).

Main areas of the scientific interest are:

- Natural Hazards: Earthquakes, Tsunamis, Volcanoes, Floods, Forest fires.
- Nonlinearities: Small disturbances and turbulences, Risk and damages assessment and mapping, Human groups' behavior during extreme situations.
- Applied Geophysics: Oil and gas prospecting, Signal processing and data analysis, Antarctic research.
- Space Research: Remote sensing, Vulnerability assessment.
- Ecological Catastrophes: Natural hazards triggered technological disasters, Intentional acts.
- Prevention and protection: People safety, Risk management and mitigation, Land-use planning.

Author and co-author of fifteen books and monographs and more than three hundred papers in the national and international journals.

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