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ARCHAEOSEISMOLOGY IN BULGARIA

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ABSTRACT. The paper discusses the new born discipline – archaeoseismology and its possible applications and development in Bulgaria. The rich archaeological environment of Bulgaria is accepted during the last years as a general fact. On the other hand – the fast and effective development in seismology provides equipment and infrastructure which could be useful for an interdisciplinary approach together with archaeology. Some effective examples as a result of the cooperation between the specialists of both disciplines are presented and discussed. The future development of this symbiosis is expected.

Introduction

The increased knowledge and the introduction of new interdisciplinary methods of investigations and interpretation lead to new, more effective and sophisticated approaches and methodologies used by different disciplines. A new fast developing approach in the last years is the symbiosis between seismology and archaeology. The newly born discipline is archaeoseismology and its first steps and development in Bulgaria are the main goals of this paper.

Many new and exiting discoveries during the recent years (for example, the Starosel temple, the Cybele temple near Balchik, etc.) show the effectiveness of the archaeoseismology approaches for the interpretation of data. On one hand, the area of present Bulgaria is seismically highly active. On the other hand there are a lot of ancient heritage which is discovered and/or in the phase of new excavations and investigations. This is the main goal of this paper – to combine the efforts of the specialists in different disciplines – archaeology and seismology to reach new and valuable results. Both disciplines could be supported by the high effective recent methods of the prospective geophysics and distant space and aero methods.

Unfortunately no targeted investigations have been focusing on the specific archaeoseismology sites and features. Some sporadic and occasional evidence show that such approach can have significant importance and implementation for the development of our knowledge in this field. The Starosel temple, the Cybele (Balchik – Dionisopolis) temple and some other sites described below, show the effective way to study and interpret the observations related to natural disasters effects on the ancient sites and the useful information, which can be extracted by such investigations.

Archaeology with its methods of data collection is a discipline which increases the knowledge about features covered by soil layers and preserved as archaeological sites. Frequently the preserved artefacts keep information about the destructive hazardous events – like volcanic eruptions, meteoritic impacts, earthquakes, landslides, tsunamis, floods, epidemics, etc., that have affected the inhabitants of the ancient world (cities, villages, singe or multiple temples and castles, etc.). The important methodological issue is to separate and explain the observations, keeping their original and not disturbed facieses. Frequently it leads to contradictions – sometimes to display the preserved artefacts in their original environment, it is necessary to remove other (very often) important parts, preserving the influences of negative factors.

Archaeology in Bulgaria has a really fast and remarkable development during the last several decades. The newly discovered and intensively investigated sites like Perperikon, Tatul, ancient Nessebar (Messembria) ancient Balchik (Dionisopolis), the ancient Valley of the Thracian Kings (Starosel, Golyama Kosmatka, etc.), show many and new prospective sites for future investigations. The published papers and books (Gergova et al., 1995; *The Ancient Civilizations…,* 2007) show the great archaeological heritage of Bulgaria from the most ancient times (Palaeolithic and Neolithic) through the Pre-Hellenistic, Hellenistic and Post Hellenistic (Roman) times. To study and preserve all these sites – a new interdisciplinary approach is needed.

Seismology is a discipline with application of accurate methods of measurements. It is a combination of the descriptive methods and approaches (the historical seismology) and the new and sensitive equipment registrations (the recent seismology). Due to many circumstances the history of seismology shows a development from descriptive to measurements phase. From another side the old and not so reliable and accurate data present in cases important evidence – the possibility to collect and interpret from a scientific point of view, the natural phenomena – earthquakes as measurable

units. It is well known by the history of seismology that the longest world catalogue – the Chinese catalogue – consists of data for a period of about 3000 years. Only about 100 of them are covered by the instrumental measurements.

The fast development of seismology during the last years in Bulgaria, the new and sophisticated equipment of the National Seismological Network, the recent fast and reliable data exchange between seismological centres in the Balkans and all over Europe, provide a real scientific background for actual and serious scientific investigations in the field of seismology.

A huge part of the historical seismology is based on descriptions, chronics and other historical documentation from which the seismologists can extract the essential and important information about past earthquakes and other natural disasters. During the last years the so called paleoseismology was developed based mainly on the geological evidences 'writhen' by recent and ancient geological events and phenomena and their influence to the surface geological layers and other geological features – active faults and cracks, seismodislocations and other phenomena. All of these have recorded and preserved the seismic influence on the investigated features. The historical documents prepared during the written history of the mankind provide also many descriptions and other evidence in writhen form (texts, pictures, chronics, etc.) that give information of primary importance to seismologists about huge cataclysms (very often earthquakes). There is a time interval, between the writhen histories (when the information about the strong regional or local earthquakes could be found only in the written documents) and the mankind history before letters were invented. These are time periods when great historical events occurred (like the "Migration Period") and during which a lot of information have been lost due to the destructions, invasions, religious and antihuman behaviour. The time interval when data could be extracted is located at a very important time period – between the paleoseismology studies and the written documentation, which is not always complete in relation to the seismic events. The traces left on different archaeological sites could be retrieved by the methods of archaeoseismology.

Archaeoseismology have been applied in many countries. The leading positions have Italy, Greece, Turkey, Middle East countries and others. The interest is increasing, because natural events bringing the most powerful forces are responsible for the collapse of prosperous societies. The Pompeii city is one of the most famous examples of the disappearance of an ancient town due to disaster (volcanic eruption – Vesuvius) that occurred in 79 AD. According to the experience of the Italian specialists there are some clear effects of the earthquakes near Naples, Siracuse, Bary, on Sicily, etc. Similar problems were related to the Santorini volcanic explosion in the XVI c. BC that are considered as bringing the end of the Minoan civilization. There is a large list of such events which influenced the ancient populations and civilizations especially along the coastal areas of the Mediterranean Sea and the islands.

Similar effects (some more clear, some – not so) have been discovered in the neighbouring and other countries. For example, near Odrin (Edirne; Adrianopoulis) during the excavations of an ancient tomb the scientists have discovered buried walls, which show clear evidences of fault movements printed on the moved walls of the ancient tomb (Pavlides et al., 2008). Several examples are known for the destruction of ancient structures on Crete, Greece, Turkey, Jordan, Syria, Algeria, etc.

Some more evidence could be extracted from the detailed studies of ancient sites in Bulgaria like the Sveshtary tomb, the Perperikon site, the Antonovo site, the St.George and St. Sofia churches in Sofia, etc. May be more focused investigations in the areas with well known seismic activity such as Plovdiv Seismic Zone (PSZ), Gorna Oryahovitsa Zone (GOZ) , Sofia Seismic Zone (SSZ), Shabla-Kaliakra Zone (SKZ) and Kresna-Kroupnik Zone (KKZ) can improve our knowledge about the seismic effects on the ancient people and their settlements. On the other hand – newly discovered archaeological sites, can help seismologists to clarify many parameters (even to discover new events) of the ancient earthquakes – local or regional.

Methodological aspects

What could be the main methodological aspects of the archaeoseismology development in Bulgaria? So far, there are only a few attempts to discover the link between seismology and archaeology in Bulgaria (Anastasov et al., 2001).

The suggested methodology includes the application of the main methods of investigations in archaeology and seismology (with additional incorporation of the distant – geophysical prospecting and space imagery and *in situ* methods – geological and laboratory investigations): discovery and excavation phases of the respective sites; identification and dating of the discovered artefacts; assessment of the possible influence of the seismic events on the discovered features.

According to our view and the world archaeological practice, several directions of investigations are obligatory (there are enough seismological and archaeological data and information to use them together effectively): data and information about known ancient and historical seismic evidence, which happened on the territory of Bulgaria; other remote seismic sources which could affect archaeological sites in ancient times; main archaeological sites, which were possibly affected by the local or regional seismic events; overlap of the known seismic zones with major archaeological sites in order to search for possible seismic effects on them.

The seismic effects could be produced as a result of the seimogenesis (like faults scarps, etc.) and/or by the macroseismic influence and/or secondary generated natural events:

- possible interpretation of the observed phenomena and their relations with earthquakes or similar geodynamic phenomena;
- search of complex effects proving information about the different natural disasters which affected the archaeological sites (frequently the seismic events triggered secondary effects like landslides, tsunamis, boiled and liquefied soils, etc.);
- additional investigations using methods of the prospective geophysics about layers identification (by electric and geomagnetic methods), localization and outline of the similar objects not yet excavated (by electric, magnetic and probably seismic reflection methods), laboratory measurement of the

physical properties of the rocks and environmental deposits as well as the properties of the artefacts;
- additional use of distant (aero and space) methods for localization and deeper investigation to the non easy available and difficult to reach objects (in the mountains regions, covered by soils and/or vegetation, etc.);
- use of the geological methods for rock and mineral analysis and identification of the discovered artefacts and objects (Ranguelov, 2001).

The archaeological sites in Bulgaria have been selected on the base of geographcal location and time of existence and development. Several time intervals have been investigated: the most ancient period – up to the VI-V c. BC, the 'Thracian' period – V-IV c. BC, Hellenistic Thracian period VI-II c. BC, Roman Thracian period – I-IV c. AD. The comparison with the seismic activity known so far, shows the possible influence on the ancient sites.

Up to the VI-V c. BC there is no much evidence, which could support the investigations of seismic effects on archaeological sites. Then the V-IV c. period provides better opportunity for search of seismic effects on the Thracian tombs, temples and other ancient buildings. For example, prospective sites are: Pistiros – M7.5-8.0; Philipopolis – M7-7.0; Alexandrovo – M6.5-7.0 (PSZ); Kabile (JMB) – M5.6-6.0, Sevtopolis, Shipka, Kazanluk – M7-7.0, Starosel, Sveshtari – M5.0-6.0. The most prospective is the Hellenistic period – VI-II c. BC with possible effects to be investigated at: Babiak, Belovo, Dobrashtica (KKZ), Pistiros (PSZ), Bisone, Durankulak (SKZ) – M7.5-8.0, Philipopolis, Halka Bunar, Malko Turnovo, Yabalkovo, Brezovo (PSZ) –M7-7.0, Alexandrovo, Cepina, Dragoina(PSZ) – M6.5-7.0, Sevtopolis, Shipka, Kazanluk, Krun (GOZ), Resilovo, Dolna Koznica – M7-7.0, Starosel, Sveshtari, Rozovets – M5.0-6.0.

The next is the I-IV AD period for which the sites with potential for additional information are: Nikopolis ad Istrum (GOZ) – M6-7, Philipopolis – M7-7,5 (PZS), Pautalia (Kustendil Zone), Serdika (SZ) – M6.5-7. From the historical data and information there are only a few examples of strong earthquakes during the period VI c. BC – IV c. AD. The most famous one is the seismic event from III (I?) c. BC described by Demetrius Calatius, Strabo and Pseudoskimnos as a major catastrophe due to which the ancient Greek colony Bisone "sank in the sea waters" and have been moved up (see below).

It is important to mention that the most major archaeological sites (more than 50%) are located outside the well known seismic sources in Bulgaria. So, there, only macroseismic influence and some secondary effects could be expected. Nevertheless, the sites in the rest territories could be a useful source of knowledge about the possible primary and/or secondary seismic effects on the ancient structures and artefacts.

Preliminary seismological data and expectations

The seismicity data and information could be extracted mainly from the Historical Catalogues of earthquakes. More than 150 seismic events with magnitude greater than 5 have been documented on the territory of Bulgaria. The space distribution of these events is presented on Fig. 1. The time distribution up to XX c. is shown on Fig. 2. The stronger events (M>6.0) during the XX c. are presented on Table 1. The frequency of the magnitude-time distribution for the XX c. is displayed on Fig. 4.

Table 1
Earthquakes in Bulgaria with M>6.0 during the XX century

yyyy/mm/dd	Long.N	Lat.E	Depth, km	M
1901/03/31	43.4	28.7	14	7.2
1901/07/30	43.6	28.7	15	6.1
1904/04/04	41.8	22.9	15	7.1
1904/04/04	41.8	23.1	18	7.8
1904/04/10	42.7	22.7	36	6.5
1905/10/08	41.8	23.1	19	6.4
1913/06/14	43.1	25.7	15	7.0
1928/04/14	42.2	25.3	10	6.8
1928/04/18	42.2	25.0	16	7.0

This information reveals at least 2 important facts: the seismicity in Bulgaria appears non randomly in space, but following the main seismogenic zones (Fig. 2); the seismicity in Bulgaria appears like episodes with different duration (Fig. 3 and 4); there are several intervals (mainly at the beginning of the I millennium (from 1 AD to the end of 999 AD) when a lot of seismic events are missing. Two explanations are possible: no strong earthquakes have occurred (less probable) and no earthquakes were documented (i.e. they occurred, but have not been documented in some way). The second hypothesis looks more probable.

If such a hypothesis looks more probable, it can be used in the search of more seismic events with the help of archaeoseismological methods. Most of the well known and mapped archaeological sites cover just this time interval. In this way they could provide clear and more reliable information about the past seismic events. Moreover – despite that the earthquakes occurred in the different seismogenic zones, most of the archaeological sites are located near or on such zones. As it could be seen from the figures above the area of the Bulgarian Black Sea coast looks most perspective for investigations.

Some examples of archaeoseismological findings and interpretations

Non-systematic research in Bulgaria has been applied to different archaeological sites in order to discover the respective earthquake evidence. Such studies proved that one or another archaeological site was affected by some sort of seismic influence. The combination of the methods of archaeology (relatively reliable in dating of different objects) and seismology (relating an archaeological object to an ancient seismic or other natural disaster, but with no evidence for an earthquake) could give much more information about the correct assessment of what has happen and to translate this in scientific geophysical measurable units – intensity, magnitude, size of the affected area, etc.

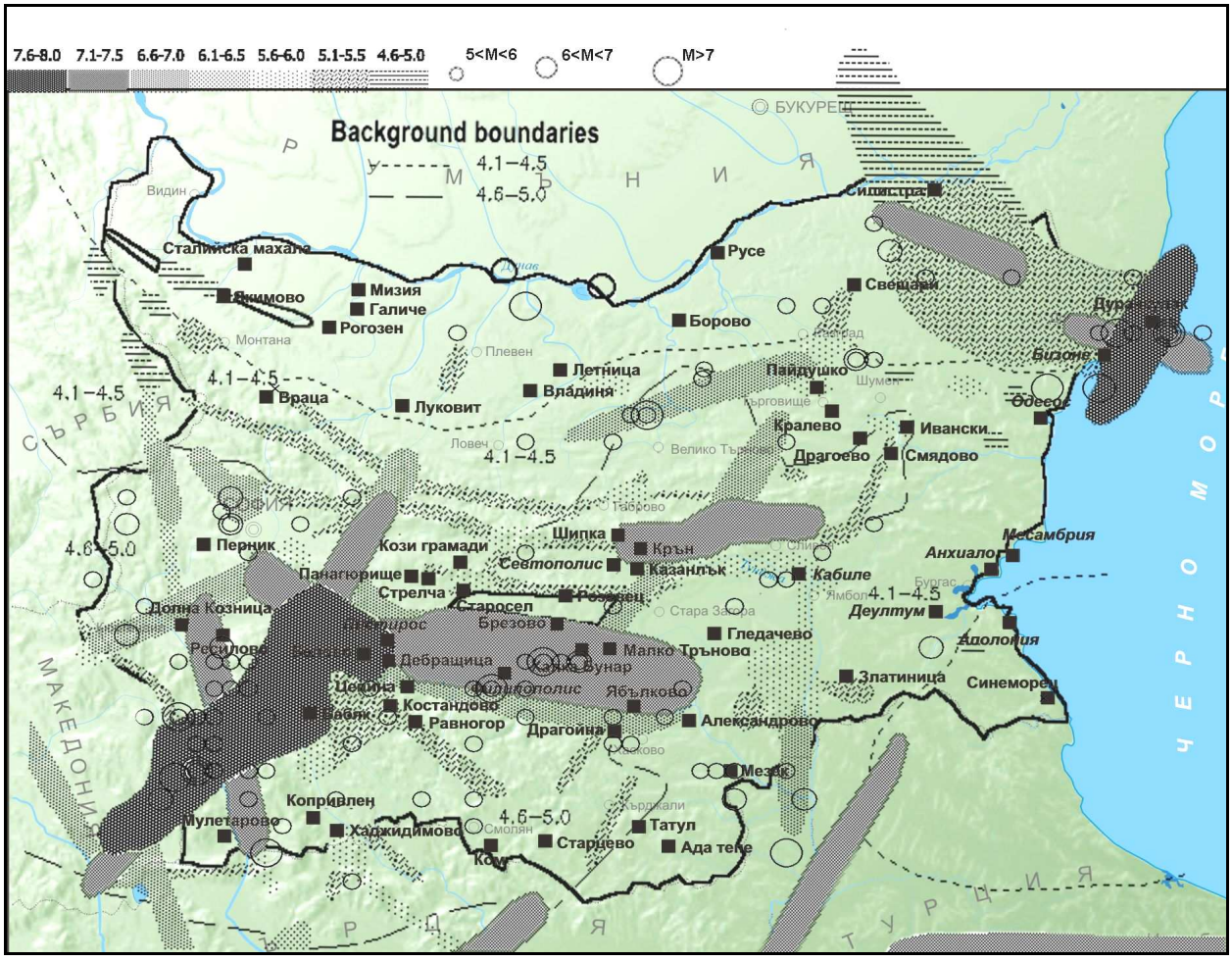

Fig. 1. Locations of the seismic source zones (expected Mmax: 4-8) and the main archaeological sites of the country

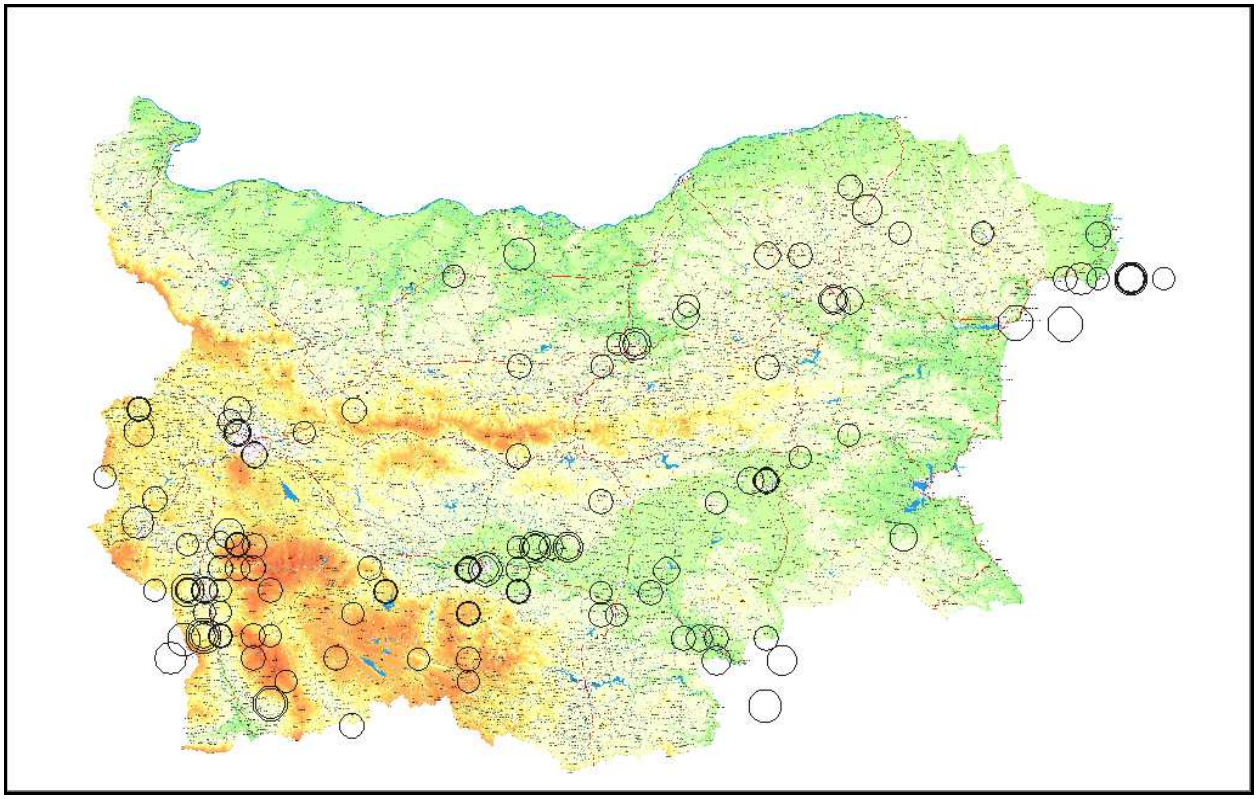

Fig. 2. All known earthquake epicentres in Bulgaria and the near surroundings with magnitude M>5.0

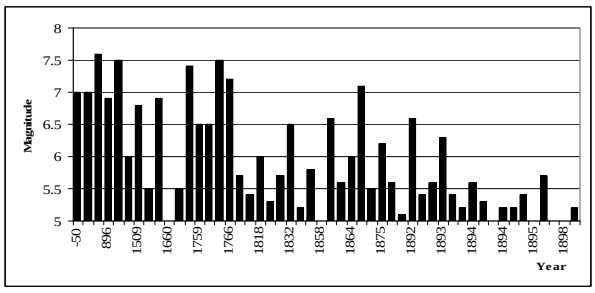

Fig. 3. Magnitude-time plot of the earthquakes in Bulgaria with M>5.0 up to XX century

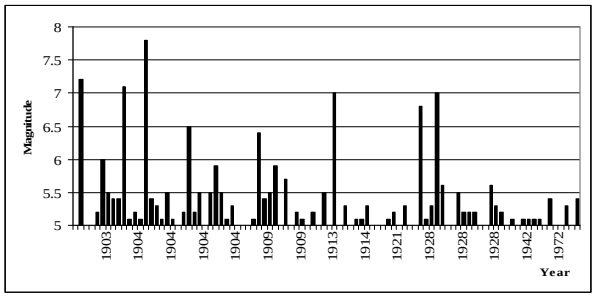

Fig. 4. Magnitude-time plot of the earthquakes in Bulgaria with M>5.0 during the XX century

Just a few so far are the cases of combined multidisciplinary approach using archaeological data and seismological evidence. They show the huge potential for transfer of knowledge between the disciplines and the possible application of the obtained results. Some of the most impressive of them are listed.

Cybele temple in Balchik

Starting excavations in April 2007 the Cybele temple presents an extreme example of a relatively well documented complex disaster event: influence of probable(?) effects of earthquake(s), a simultaneously (and/or consecutively) tsunami and landslides effect – destructing and covering the remains of the temple. The 543 AD earthquake (the most probable reason of the temple's destruction), was mentioned by E. Guidoboni in "The Mediterranean Earthquakes", as a possible generator of a local tsunami. The excavations discovered a low (down to the floor of the temple) thin layer of burned material mixed with the sand and sea molluscs shells. In this layer a lot of marble artefacts have been found. 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 sponsors of the ancient temple was discovered. After the reconstruction all parts of this plate we re-fitted, which shows that the plate was broken on the floor and no parts were extracted afterwards. This means that the breakage occurred due to falling down of the plate parts during an earthquake. Then the parts have been mixed most probably due to the sliding inside masses. The preservation of the walls to a certain height means that these walls have been buried by the surrounding masses.

The total reconstruction of the processes, as seen form the ruins, could be the following (Fig. 5; Ranguelov et al., 2008). Burning roof followed by collapse (due or not to earthquake (or separately of it); earthquake, which destroyed a large part of the temple (cracks and slightly moved visible elements on the walls and the floor) and the interior marble elements – plates, statues, etc. – some of them broken due to falling down; tsunami which brought sand and molluscs shells; landslides (at once or several times) which filled the space of the destroyed temple, mixed some artefacts 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 archaeological 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 of Bisone in the III (I?) c. BC.

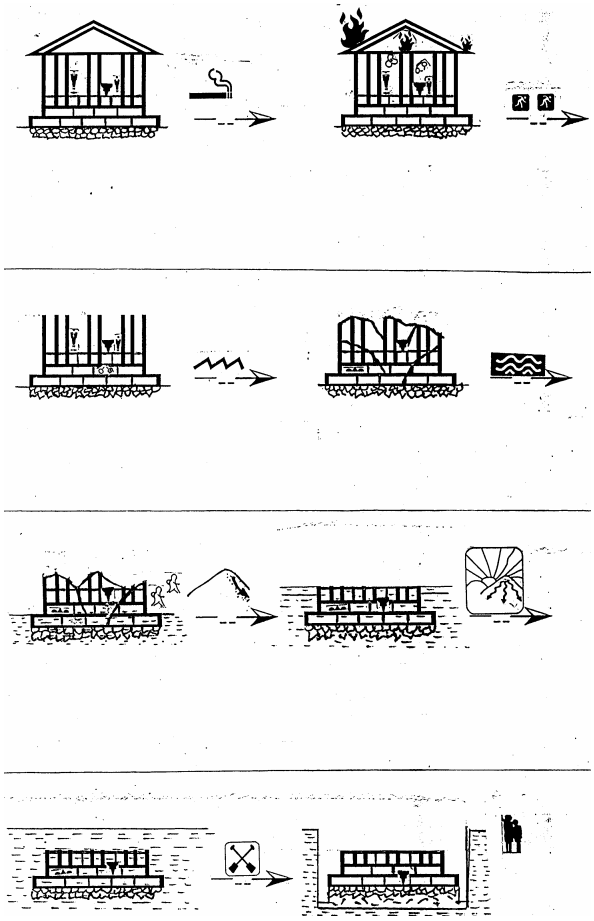

Fig. 5. General reconstruction of the scenario of the Cybele temple's destruction and preservation

This leads to relocation of the port-city, situated near the shore to a more secure position up the hills and to a new development of the town. Probably the same has happened with Dionisopolis (Balchik) after the destructive 543 seismic event. These heavy disasters sometimes lead to the relocations of relatively large colonies (town and villages with their inhabitants). They had devastating consequences for the ancient people, changing their style of everyday life and work.

Starosel Thracian temple

Excavated in 2000 (Kitov, 2003) there are several clear evidences supporting the idea that the temple was affected by an earthquake (Anastasov et al., 2001): the sheet like cracks and destroyed parts of the big and heavy stones at the entrance

walls; the cracked and moved horizontally thick marble plate (about 10 cm) at the entrance; the temple is located near the Plovdiv seismic zone, and all model calculations show that such effects could be produces by an earthquake.

The paleoseismological excavations (done by the Geological Institute of the Bulgarian Academy of Sciences) established high amplitude vertical movements of the seismic dislocations visible in the strata due to the 1928 event and to some earlier historical events (for strata buried under the surface soil).

Conclusions

Following the observations, the known and newly discovered sites many new findings could be expected in the near future. The prospective areas of increased interest to the archaeoseismological research could be: the region of Varna (related to the Shabla-Kaliakra seismic zone – SKZ); the region of the South Bulgarian Black Sea coast; the region of Plovdiv (Plovdiv sesimogenic zone – PSZ); the region of SW Bulgaria (due to the influence of the Kresna-Kroupnik zone – KKZ); the area of the Central North Bulgaria (the Gorna Oryahovitza zone – GOZ); the area of Sofia and surroundings (SZ).

From the seismic sources located outside Bulgaria: the Vrancea zone (with possible effects over North and North east Bulgaria); the Marmara Sea and Odrin (Edirne) zones (with possible influence over South and South East Bulgaria); the Morava zone (over West Bulgaria).

It must be mentioned that these are mainly the regional zones. The local influence can be expected everywhere when an earthquake greater than M>5 occurrs and could create visible consequences. For example, a prospective site appears to be the Nikopolis ad Nestum area – near the Mesta seismic zone. Recently observed facts on some local archaeological sites show that an influence can be expected even from small shocks (for example the Kurdjali earthquake with M4.3 and its influence on Perperikon archaeological site (Dobrev et al., 2008).

The comparison between the active seismogenic zones and some major archaeological sites in Bulgaria is performed, showing a lot of overlapping of locations. This could be used for focused search of archaeoseismiligical evidence for past earthquakes and possible estimations about their parameters in recent scientific terms. A remarkable example of newly discovered sites, influenced by ancient earthquakes and other secondary generated hazard is explained. The symbiosis between seismology and archaeology could be rather productive, perspective and prospective tool for a better study of the cultural and historical environment of Bulgaria.

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