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SEISMO-ARCHAEOLOGY IN ROMANIA: THE ANCIENT EARTHQUAKES AS A PATH TO FUTURE KNOWLEDGE

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Abstract

The earliest chronological data on seismic events in the history of Romania date from the 10th century, but the data on strong earthquakes from the intermediate depth source Vrancea are limited to the 19th and 20th centuries. To compensate for this gap, we can turn to seismic archaeology or archaeoseismology, an interdisciplinary science based on archaeological and engineering methods and data. In this context, we present data for the initiation of the study of the possible impact and seismic damage to sites and settlements, castra, forts and Roman vallums in Dacia. These were located in seismic zones of southeastern Dacia/Moesia Inferior, southwestern Dacia - Dacia Malvensis. Of interest is the line of forts on the Limes Alutanus and Limes Transalutanus, the Danubian Limes - in Dacia Malvensis, as well as in Moesia (beyond the Danube), areas exposed to strong accelerations of 0.20-0.25 g. As a result, the research should prove the years of impact and damage or destruction of some constructions by earthquakes, so that we have an extended basis for future hazard and seismic risk assessments.

Key words*: earthquake archaeology, Roman Limes, Vrancea seismic source.*

INTRODUCTION

Archaeoseismology is an interdisciplinary science, based on archaeological methods and data, in combination with seismology and engineering approaches, able to prove and to interpret damage or destruction of artifacts by the earthquakes of the past (buildings, public works, heritage etc.), with disorganization of public life etc. (Galadini et al., 2006).

Seismicity in Romania is strongly dominated by the Vrancea source, in the curvature area of the Carpathian Mountains. Earthquakes with magnitudes over 7 and with depth of foci between 60-70 km and 170-220 km, give strong shaking on some 50% of the territory in the eastern and southern Romania and causes transboundary damage at, in north of Bulgaria, in R. of Moldova and S of Ukraine (Bălan et al., 1982). Some other sources exist, as superficial (with depth of foci less than 5 km) and crustal (or normal), with depth of foci between 5 and 30-60 (?) km. In Dobrudja, there is an exposure to local crustal sources and northern Bulgaria and Black Sea crustal sources. Scientists need more data about the seismicity in the first millennium, because the Romanian Catalogue of earthquakes gives scarce historical information, only since 984 (NIEP Romplus Catalogue, 2021).

The lack of instrumental data gathered on Romanian territory was a cause of long-term under evaluation of seismic loads in buildings design. The unique accelerogram of March 4, 1977, Vrancea earthquake, obtained in INCERC Bucharest, allowed a huge progress in code evolution (Bălan et al., 1982; Berg et al., 1980; Georgescu & Sandi, 2018; Georgescu et al., 2022). However, there is still a need of complementary data for a better probabilistic assessment of seismic hazard.

MATERIALS AND METHODS

The methodological concept for identifiing the date of damaging earthquakes by archaeoseismology includes the following main steps (Galadini et al., 2006):

- identification of damage in a site/stratigraphy and try to associate/dissociate causes of damage from accidents, invasions or other hazards versus earthquakes;

- evaluation of possible causal seismic sources and local geological factors; find other sites where earthquakes of the same source have caused damages simultaneously;
- finding chronology - year/period of such damages; providing dating with coins, pottery, C 14 etc.

We may be thus concerned about where to search for impact of ancient Vrancea earthquakes in Dacia (actual Romania) and Moesia/Thracia (actual Bulgaria)?

The 1802 Vrancea earthquake produced a large area of IX to VII degrees MSK intensities in Romania, while in Bulgaria cover an important area of VII degree (Sagalova, 1968). Other authors, as Radu & Utale (1992), give MSK intensities in Bulgaria on a greater area of VII degree, including Sofia (Figure 1a).

Figure 1a. The isoseismal map of Great Vrancea 14/26 October 1802, Mw 7.9 earthquake, after Sagalova, 1968

In 1838 the MSK intensities in Bulgaria were from VII (near Danube) to VI and V in rest, while strongly felt in Vratsa, Trojan, Veliko Tarnovo, Drianovo (Rogozea et al., 2014) (Figure 1b).

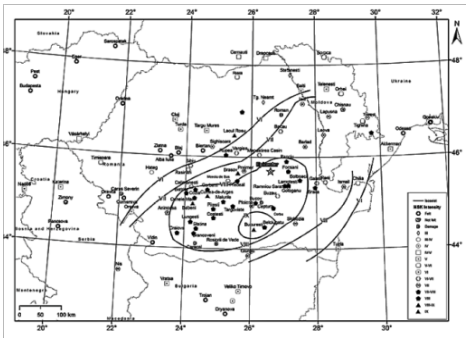

Figure 1b. The isoseismal map of Vrancea, January 23, 1838, Mw 7.5 earthquake. Seismic intensity map on MSK scale based on revised data of Rogozea et al., 2014

In the November 10, 1940 Vrancea earthquake (Figure 2a), caused a large area of VII and VIII degrees MSK intensities in Romania, with peaks of IX in epicentral zone; in Bulgaria, there is an area of VI intensity degrees MSK in northeast (Leydecker et al., 2008).

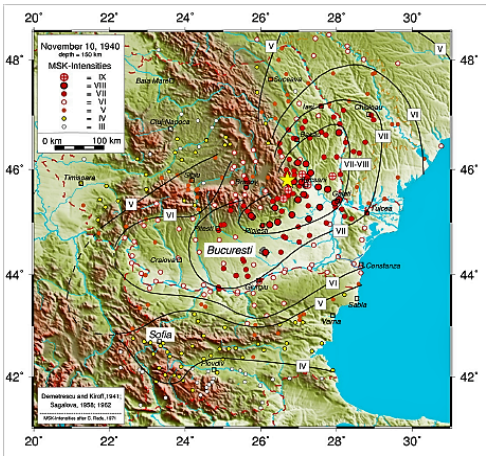

Figure 2a. Macroseismic maps in MSK intensity - Vrancea, November 10, 1940, Mw 7.7 earthquake (Leydecker et al., 2008. CC BY-SA 3.0 license) (Accessed April 2021)

In the March 4, 1977, earthquake (Figure 2b), the directivity towards S and SW of Romania was obvious, with intensities of VII and sites of heavy damage as over VIII MSK.

The shaking almost destroyed the Romanian town of Zimnicea and caused collapse of three high-rise buildings in Bulgarian town of Svishtov, both on Danube banks. In Bulgaria, many places with VIII degrees MSK occurred in

north, up to 50 km south of Danube, with large areas of VII intensity degrees MSK spread towards Sofia (Leydecker et al., 2008; Solakov and Simeonova, 2012).

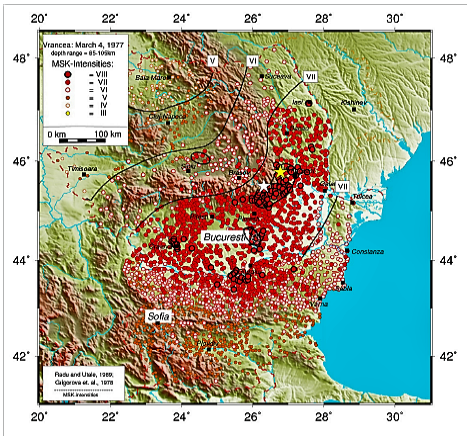

Figure 2b. Vrancea, March 4, 1977, Mw 7.5 earthquake (Leydecker et al., 2008. CC BY-SA 3.0 license) (Accessed April 2021)

It is important to emphasize that in 1977 Vrancea earthquake, the INCERC Bucharest Seismic Network recorded a unique accelerogram, proving a long-period pattern of Vrancea motions waves with potential of damage for tall and slender structures, also at large distances (Bălan et al., 1982; Berg et al., 1980; Georgescu & Sandi, 2018; Georgescu et al., 2022). Although the general directivity of Vrancea earthquake is NE-SW, the May 31, 1990 Vrancea earthquake (Mw 6.4) INCERC records proved a directivity towards S-E, in Dobrudja/Scythia Minor (Borcia, 2006; Georgescu & Sandi 2018). In other terms, concerning the Vrancea source, there are some specific questions:

- earthquake catalogue data (NIEP Romplus Catalogue, 2021) with data since 984 allowed the study of sometime-magnitude regularities expressed in years spans of possible great magnitude events, as 3 great earthquakes for an average of 100 years (Enescu, Marza & Zamarca, 1974). Other assessments revealed some statistical cycles of 100 year as well as of some quasi-cycles of 300 years (Purcaru, 1979). These patterns were detailed later (e.g., a refined exponential model by Enescu, Struzik & Kiyono, 2008).
- the challenging question is if we may assume that the seismicity was statistically the same in previous 1000 years, in terms of recurrence and/or directivity towards S-W and/or S-E, and the if the archaeological data may give answers?

Thus, we assume the premise that the archaeological surveys may give more chances to find simultaneously affected sites and to confirm the patterns of recurrence, energy release and low attenuation, i.e. impact at remote sites, of Vrancea deep source.

It is very important that the seismological knowledge gathered after 1977 proves that crustal earthquakes that happens at hundreds of kilometres (e.g. events of Constantinople 477 or 583 or Skupi 518) cannot cause strong shaking and damages on Danube Limes or Moesia Inferior sites. Only Vrancea greater and deeper earthquakes have this capacity.

RESULTS AND DISCUSSIONS

The ancient Dacian local culture and architecture was based on wood and earth, while stone was available only near hills or Carpathian Mountains. The Roman conquest of Dacia since 2-nd century covered mainly the western and Central area (Dacia Superior/Apulensis and Porolissensis), north of Danube only the south/southwest area (Dacia Inferior/Malvensis). In south-west the stone was used only in some Roman defense castra, while most of military watch towers were made of wood and earth, along the Alutanus Limes and Transalutanus Limes (Teodor, 2015). The current data from excavations do not indicate seismic causes of damage. The earth and wood do not preserve the traces of damage and this is the reason of lack of testimonies in excavations on Dacian or Roman Dacia constructions that existed between Danube and Carpathian Mountains.

There are promising data of Bulgarian and Polish archaeologists about traces of earthquake damage in Moesia/Thrace on Danubian Limes. East of Danube there was a Roman Moesia/Scythia Minor, where stone was used in most of defence and civil constructions and Romanian archaeologists were able to found more data about earthquake impact. In Figure 3, there is a seismic zoning map of Romania.

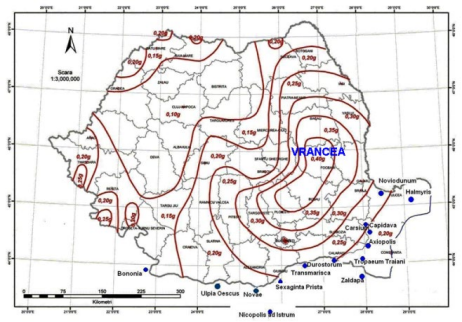

Figure 3. Seismic zoning map of Romania for IMR-mean interval of recurrence (return period) of 225 years, used for seismic design, indicating values of peak ground acceleration-PGA (Romanian Seismic Design Code 2013, UTCB-MDRT), having added the ancient Roman castra on Danube Limes, and eastern part of Moesia Inferior

Figure 4. Map of Roman Limes in Dacia. https://ro.wikipedia.org/wiki/Limes#/media/. File: Roman_Byzantine_Gothic_Walls_Romania_Plain. svg. CC BY-SA 3.0. Derivative work: Cristian Chirita (talk) Roman_Dacia.svg: Andrei_nacu, uploaded at Commons by El_Bes - Roman_Dacia.svg (Accessed April 2021)

The map shows the zones with great peak ground accelerations of 0.15-0.25 g, visible on the S-W direction in Romania, where it was Dacia Inferior/Malvensis, with impact in south all over Danubian Limes and in Moesia/Thracia. Archaeological research on Roman castra, fortifications and municipia is necessary in south/southwest of Romania in order to recover data on damage, at least in I-st to VII-th centuries, until the Danube Limes existed.

The places of Roman castra, forts and vallums on Limes Alutanus and Limes Transalutanus are depicted in Figure 4 (Chirita, 2021). In correlation with Figure 3 it results an exposure in the seismic zones with strong PGA - peak ground acceleration of 0.20-0.25 g. In fig. 4 we see on Limes Alutanus - on Alutus/Olt River 11 castra / citadels / municipia, defense stone and earth vallums, while on Limes Transalutanus - east of Alutus/Olt River there are 18 forts of earth and stone, earth vallums, in south many forts were in timber and earth.

Timber and earth structures are less vulnerable to earthquakes. Remnants and traces of seismic damage possibly to find only in case of some larger stone constructions. Many sites not yet excavated.

Castrum Arutela on Limes Alutanus (on River Alutus/Olt, near Calimanesti, in Vrancea impact zone) was erected in 138 during Hadrian Emperor reign, in the Roman province of Dacia on the Limes Alutanus by a unit of Syrian archers (Suri Sagittari). It was destroyed by a flood of Alutus/Olt in 3-rd century.

In Figure 5 it is shown the reconstruction of Porta Praetoria done in 1982-1983 (https://ro.wikipedia.org/wiki/Castrul_roman_Arutela).

Figure 5. Castrum Arutela. Porta Praetoria (reconstruction) as seen from the River Olt (Photo Georgescu, E.S., 2022)

Castrum Jidava on Limes Transalutanus (near Campulung-Muscel, exposed to Vrancea and local crustal seismic source) was erected in 190-211, under Emperors Commodus and Septimius Severus.

It is the only stone castrum of Limes Transalutanus. It was destroyed by fire at 244-245 after Carps invasion, when all forts of Limes Transalutanus were destroyed. Excavations were done after 1962 with consolidation and partial reconstruction of 1970 (Petolescu & Cioflan, 1995; Popescu & Popescu, 1968, 1970) (Figure 6) https://ro.wikipedia.org/wiki/Castrul_roman_Jidava).

Figure 6. Castrum Jidava on Limes Transalutanus. Reconstruction of castrum main gate/Porta Praetoria, view from inside (Photo Georgescu, E.S., 2018)

As cities and citadels in Dacia Malvensis, the first glance gives:

- Romula/Malva (Resca)–Capital of Dacia Malvensis, Municipium during Hadrian reign, Colonia during Septimius Sever, inhabited until IV-th to VI-th century (https://ro.wikipedia.org/wiki/Romula);
- Sucidava (Corabia-Celei) on Danube, in front of Ulpia Oescus (Moesia)-fortified with 8 towers in IV-VIth century; it was devastated by Huns in 443 or 447? (https://ro.wikipedia.org/wiki/Sucidava).

Concerning the seismic exposure in Dobrudja/Scythia Minor/Moesia Inferior, the crustal Pontic seismic sources impact is known for some sites, as the Roman edifice with mosaic in Constanta (in VI-th century), also a presumable seashore settlement in Callatis and traces of possible earthquake in Histria.

Vrancea source was considered too remote, but the Triumphal Monument Tropaeum Traiani in Scythia Minor suffered the collapse of its upper part, sometime, between 3-rd and 6-th century. Trophy pieces were found fallen in NW-SE of the ruin, just in Vrancea source zone direction (Tocilescu, Benndorf & Niemann, 1895; Georgescu 2014; Georgescu 2015).

The Civitas Tropaeensium/Municipium Tropaeum Traiani: excavation data of east tower A prove some cracks of foundations towards the end of III-rd century and large construction works in of citadel at the beginning of IV-th century (findings based on field works of Ioana Bogdan Cătăniciu in http://www.cimec.ro/arheologie/tropaeum/cetatea/index.html), the works could be related to the Licinius and Constantine “de fundamentis” reconstruction. Such damage and reconstruction were caused by an earthquake or a landslide? It was Vrancea or a crustal neighboring source?)

Concerning the seismic exposure on the right bank of Danube Limes, Moesia/Thrace, we may refer to some areas beyond the Danube Limes in present Bulgaria as a part of Thrace, for some historical periods, while for later periods some territories changed their administrative allocation from the province of Thrace to Moesia Inferior, probably in the last decade of the 2nd century (cf. Boteva 1996, 173). The maps of seismic zoning from Romania and Bulgaria show for Danubian Limes and Moesia - exposure to Romania Vrancea intermediate earthquakes with PGA - peak ground accelerations of 0.15-0.25 g taller or greater buildings existed in ca. 70 places at S and S-E of Danube (colonia, municipia, castra, castella and vici) in present Serbia, Bulgaria and Romania.

In Moesia/Thrace there is also exposure to crustal earthquakes of north Bulgaria, to Gorna Oryahovitsa source zone PGA - peak ground accelerations of 0.11-0.15 g (Bulgaria’s seismic hazard map for 475 years return period, 2012). In Bulgaria - south Dobrudja there are sources of Cape Shabla - Kaliakra and Dulovo.

As castra and municipia with confirmed earthquake traces in Moesia/Thrace, we identified: Svishtov-Novae legionary fortress headquarters and episcopal complex, Ulpia Oescus/Gigen with Fortuna Temple, Nicopolis ad Istrum/Nikyup-with important buildings, Sextaginta Prista/Durostorum with a basilica etc.

The synthesis of existing archaeological data provides a preliminary attempt to a chronological summary of damaging earthquakes. At a first glance, as a result of a literature review, a chronological summary of years of earthquakes and damages on Danubian Limes and adjacent zones during I-st - VII-th centuries AD, resulted as follows:

- in 80-damage and ground faults by a very strong earthquake. Dating with coins and

Carbon 14 at Novae (Svistov) - legionary bath (Dyczek, 2011; Kolendo & Kowal, 2011; Lemke, 2009-2010)
- in 170-great destruction at Civitas Tropaeensium-Costoboci invasion;
- at ca. 170-repairs at Sanctuary in Sextaginta Prista (Russe), caused by Costoboci invasion or an earthquake (Varbanov, 2013);
- in 204-disturbing or destructive unknown event, hiding of a coin heard treasure - imperial denars in Civitas Tropaeensium, final of Severians (Barnea, 2011) (could it have been Vrancea earthquake ?? and/or invasion?);
- in 238 p. Chr.-Histria was destroyed (Black Sea earthquake?);
- in 251...269-Gots destroy Civitas Tropaeensium;
- in II-nd-III-rd century-damaging earthquake at Novae (Sarnowski, 2015)
- in III-rd century-Capidava baths were destroyed by an earthquake (R. Florescu cited in Opriș, Rațiu & Potârniche, 2018);
- in III-rd century-distructions and reconstructions at Nicopolis ad Istrum (Rizos, 2013);
- in 316-the reconstruction of Civitas Tropaeensium by Licinius and Constantin, after invasions? could it be related also to earthquake damages ??;
- in 326-327 a Durankulak–Shabla-Kaliakra source earthquake;
- after III-rd century-Nicopolis ad Istrum–building 7 destroyed by an earthquake with directivity of Vrancea; Dikov (citing Tsarov) 2018, excavations confirm that after III-rd century there was a very damaging earthquake;
- at the end of IV-th century or early V-th century–two warehouses destroyed by earthquakes at Nicopolis ad Istrum (?? Vrancea ??), (Rizos, 2013);
- in 370-380's Novae Center Sector XII - strong earthquake well dated with coins (Dyczek, 2018);
- in the late IV-th/early V-th century - two buildings destroyed at Nicopolis ad Istrum (Rizos, 2013);
- in 544/545 or 543 Earthquake of M 7.5 - tsunami at Kavarna, Cape Kaliakra–Temple of Cybele of Dionysiopolis (Balcik) and the harbour of Greek colony Bisone (Kavarna) destroyed by an earthquake and tsunami, with landslides. Similar Odessos and Afrodision; 544/545 (Guidoboni, 1989; Ranguelov et al., 2008);
- in 488, 515, 557-damaging earthquakes at Novae (??) (Biernacki, 2013);
- until first half of IV-th century - a disaster event at Novae (Gots or earthquake?) (Zakrjewski, 2015);
- in the first third of V-th century until beginning of VI-th century–damaging earthquake at Novae (Sarnowski et al., 2018; Sarnowski, 2015; Sarnowski, T., Kovalevskaja, L., & Tomas, A., 2008; Sarnowski et al, 2016);
- to the end of V-th century-beginning of VI-th century - Roman edifice with mosaic of Tomis destroyed by a Black Sea earthquake;
- to the end of V-th century-beginning of VI-th century-earthquake (?? from Vrancea ??), heavy damaging of basilica in Durostorum (Atanasov/Russev, 2009);
- in the second half of VI-th century-devastating earthquake at Nicopolis ad Istrum;
- in late 5th early 6th centuries the Durostorum Christian Basilica survived a considerable destruction, probably caused by an earthquake, and it was restored later (Atanasov & Russev, 2009);
- to the end of VI-th century-Ulpia Oescus (Gigen, vis-a-vis Corabia, Romania) - Temple of Fortuna-height 22 m! was destroyed by an earthquake, not by Christians! (Kabakchieva, 2015, http://archaeologyinbulgaria.com/2015/06/07/ancient-thracian-and-roman-city-ulpia-oescus-in-bulgarias-gigen-deserves-greater-publicity-archaeologist-says/), also Farkov & Kolarov, 2016, consider Vrancea earthquake as a causal event!
- to the end of VI-th century-Zaldapa decades and disappears at a decade after Avars invasion of 585 (Torbatov, 2000). Could it have been also because of earthquakes? From Shabla source? From Vrancea source?
- end of VI-th century-Capidava building C 1 destroyed by an earthquake (R. Florescu cited by Opriș & Rațiu, 2017); alternatively, some data may prove that at the beginning of VII-th century at Capidava a great earthquake (?? from Vrancea??) destroys the

Citadel, after the Avars invasion of 586 (http://cimec.ro/Arheologie/Capidava/descrie.htm);
- in the VII-th century-the Danubian Limes is considered out of function; how many other earthquakes struck in the VIII-th century ?? the IX-th century?? What may happen later?

CONCLUSIONS

Although the research is still at the beginning, the preliminary attempt to establish a framework able to facilitate finding/recovery of archaeological data about the Vrancea earthquakes impact in southern Roman Dacia proves to be fruitful.
Few oral presentations on preliminary issues on this subject were done by the author in last years (Georgescu, 2018; 2021; 2022) and the audience proved an increasing interest. The earthquake exposure is high, but the impact along the Limes Alutanus and Limes Transalutanus and in Dacia Malvensis is not yet identified in published archaeological data. However, the reevaluation of existing excavation reports may reveal and ascertain the traces of great Vrancea events in the recorded physical damage, if the archaeologists will cooperate with engineers and architects to a larger extent. Since there are many sites to search, this approach may have a potential of triggering new evaluations and producing results after further investigations and/or recovery of data.
The earthquake impact along Danubian Limes and on its influence area, as well as in Moesia/Thrace/Scythia Minor (Dobrudja), is proved by archaeological data. The impact of Romanian earthquakes is quite important in Bulgaria from Danube up to Stara Planina Mountains (some data prove that the March 4, 1977 Vrancea earthquake caused damage in Sofia, where some crustal earthquakes striking West of Romania in February 2023 were also felt!). The concurrent impact of local seismic sources, as well as the impact of other catastrophes must be ascertained.
The range of dating intervals for earthquakes causing damage/collapses, as given by existing historical/archaeological reports, is still in large range of years. Although the archaeological data are insufficient, the damage in many places is a proof of some simultaneous impact of large earthquakes along Limes and in Moesia strongly indicates the Vrancea source. After the III-rd century AD, the available data also seems to confirm a pattern of 3 great events per century. The issue of considering the earthquake damages of defence works as a favouring factor for the invasions impact, needs further investigation. The archaeoseismology has a larger potential to give more results and needs detailing and additional data gathering and recovery in all considered Dacia and Danubian Limes areas. The research should prove the years of impact and damage or destruction of some constructions by earthquakes, so that we have an extended basis for seismic risk assessments.

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