Evidence of a seismic event on Thracian tombs dated to the Hellenistic period (Sveshtari, Northeastern Bulgaria)

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Abstract
The Thracian Necropolis at Sveshtari (Northeastern Bulgaria) is composed of numerous tumuli of varying dimensions presenting different building characteristics that have a certain interest from the lithological and ritual point of view. Some have funeral chambers which provide us with useful information on their seismic history. All the chambers excavated to date have either collapsed or show evident signs of deformation: their typology and distribution presuppose a seismic event of great intensity. In particular, recent excavations have established that the earthquake in question occurred during the actual construction of tumulus No. 30 in about the 3rd century B.C. It was presumably the same earthquake that caused the nearby city of Bisone, on the west coast of the Black Sea, to slide into the sea. Structural conditions of the tombs as well as observations on the seismological history of the area indicate that the earthquake which occurred at the necropolis was necessarily much more intense than successive ones and supply useful information for a seismic reclassification of the area.

Key words *Northeastern Bulgaria – macroseismic effects – seismic archaeology – Hellenistic age*

1. Introduction

This paper reports the results of observations carried out on the damaged tombs at the Necropolis of Sveshtari (Northeastern Bulgaria) and general data on the seismicity of the area. This necropolis consists of many tumuli of different sizes and specifications, which are interesting both from a geotechnical and archaeological point of view, and sometimes contain stone tombs. The Necropolis is a testimony to Thracian culture of 2500 years ago, during the hellenistic period, whose influence was still only partial. Peculiar rituals and techniques were employed in their construction, sometimes including earth compaction, accurate thin interlayering, base smoothing and basal waterproof layer, semi-vaulted roof for small and regular tomb chambers, stone block overlapping, all to obtain a more resistent body, like natural ones, a mausoleum for the immortalization of the deceased. At the same time the tumuli give us the imprint of a long-lasting environmental and geological process. The elucidation of the causes of the observed destruction and deformations of this monument represents an interesting field for interdisciplinary studies and has given us interesting information about past history.

2. Seismicity and general data of the area

The necropolis of Sveshtari is located in the eastern part of the Moesian Platform, in a region bordered by a seismogenic area. The geomechanical model of the ground base can be considered a two-layer system with an upper loess and a lower limestone layer.

In accordance with the seismological data of the region (Grigorova and Christokov, 1974), over the past 100 years the examined area was affected by several seismic shocks (eight of them were up to VII MSK in the tumuli site), with epicenters both in the region of Shabla in Bulgaria (fig. 1) (table I) and in the Vrancea region in Romania. On the map of the predicted seismic regioning of Bulgaria (for a period of 100 years) the region under investigation shows the same parameters with an isoseismal line of intensity VIII passing very close to it (Christoskov, 1987). There are data on the most important earthquakes in the region in the last thousand years but not on the previous historical period of the existence of the monument under study (from 2400 years ago).

The region of Sveshtari is located on the Moesian Platform, Northeastern Bulgaria, constituted by sedimentary complexes, almost horizontal in layering. In the area of the Sveshtari Necropolis the uppermost part of the geological profile consists in the Lower Cretaceous limestones from the Rousse Formation covered by Quaternary loess deposits (Cheshitev and Kunkev, 1989). From a geomechanical point of view there is a two-layer system, with large differences in mechanical properties, rigid at the base and plastic in the layer where the monument was built (fig. 2). This system is not favourable to stability because the contrasting parameters between the limestone and loess layers amplify the seismic effect.

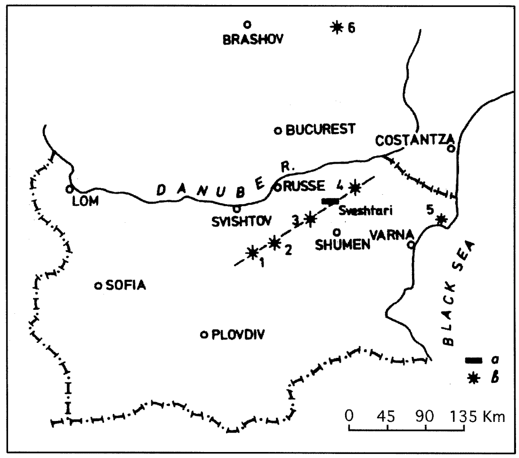


Fig. 1. Location of the Sveshtari Necropolis and of the nearest earthquake epicentres that could have given the high pressure deduced from the damage observed in the tombs. a) Location of the Necropolis; b) location of the nearest epicentres.

New experimental data on physical properties of the loess deposits using seismic prospecting gave us Vp = 330-390 m/s, Vs = 130-180 m/s and a Poisson's ratio of 0.36-0.47,

Table I. The most significant earthquakes in the last 100 years in the region of the Sveshtari Necropolis.

Seismic area	Date	Co-ordinates of the epicentre	Depth (km)	Magnitude	Intensity in the epicentre MSK	Intensity in the tumuli site MSK	Distance from the epicentre (km)
Doulovo	14.10.1892	43.3/27.6	50	7.3	VIII	VII	32
Shabla	31.03.1901	43.4/28.7	14	7.2	X	VII	150
G. Oriahovitza	14.06.1913	43.1/25.7	15	7.0	IX-X	VI	117
Vrancea	10.11.1940	45.8/26.7	135	7.3	IX	VI-VII	210
Razgrad	23.08.1942	43.5/26.7	6	5.1	VII	IV-V	31
Vrancea	04.03.1977	45.8/26.8	110	7.2	VIII	VII	210
Strajitza	21.02.1986	43.2/26.0	10-14	5.1	VII-VIII	IV	90
Strajitza	07.12.1986	43.2/26.0	13	5.7	VIII	IV-V	90

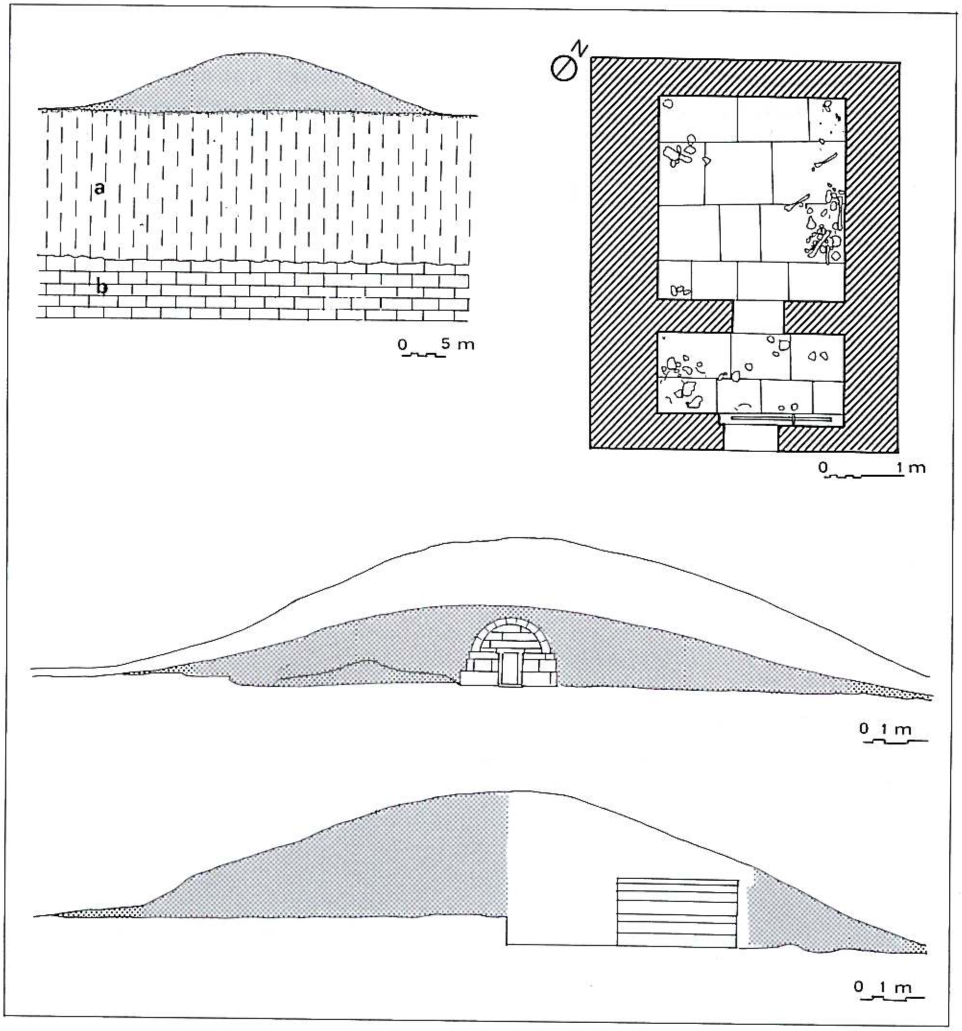


Fig. 2. Typical dimensions of the tombs in the Sveshtari Necropolis. Plan and sections of tomb No. 13.

with a rigidity modulus of 30-40 kg/m*s and a density – obtained by laboratory tests – of 1,8 kg/cc.

3. The tombs and their destruction and deformation

The tombs in Sveshtari are rectangular in plan and are covered by a semi-cylindrical vault (fig. 2). They are built of limestone blocks arranged in two vertical rows. The thickness of the walls ranges between 0.50 m and 1.20 m. The tombs discovered have dimensions of about 3.0 m by 3.0-3.5 m, and are localized in the southeastern part of the tumulus (Fol *et al.*, 1986; Gergova, 1992). After their construction the ground was piled in several steps to form a tumulus. Recent studies on the tumuli stucture of this area (Evstatiev *et al.*, 1993) have disclosed that particular techniques and rituals were sometimes employed for their piling such as earth compaction, base smoothing and interlayering structures.

All the discovered tombs show damage or problems of stability. Serious deformations were observed for the first time during the discovery of the Ginina Mogila tomb about ten years ago. Only recently, however following further archaeological excavations, did our studies and observations clearly point out that the area was especially subjected to one strong seismic event which struck the region at the time of the tomb use. A certain influence of the settling of the ground caused by the load of the tumulus over the tomb can be assumed, but these deformations are small. Even assuming that such phenomena indeed influenced the structure of the tombs, this would not explain the damage observed. Most logical seems to be the hypothesis that the most substantial destruction and deformation in the tomb were caused by a single peculiar seismic impact whose epicenter was not far from the area.

The destroyed tomb below tumulus No. 12 provided the most unambiguous evidence. The tomb was discovered with a destroyed vault, fallen facing in the northwestern lunette and two parallel blocks from the southwestern corner (fig. 3). Observations on the profiles of the tumular embankment show that at the time of its destruction the tomb had been covered by a tumular embankment consisting in a dark-coloured soil that collapsed together with its roof. It was cleared from the fallen stone blocks, and the tumulus above it was restored in the area destroyed.

The situation in tumulus No. 30 is also similar. Only a part of the walls have been preserved in the northwestern part of the tomb. The «milonitic structures» arranged in conic shape at the base of the destroyed columns that

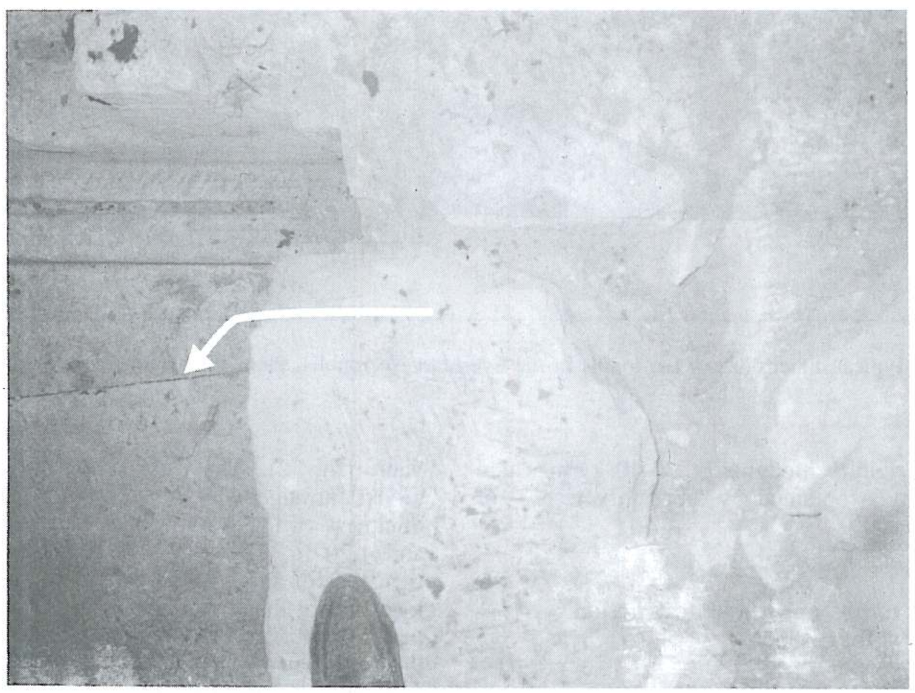
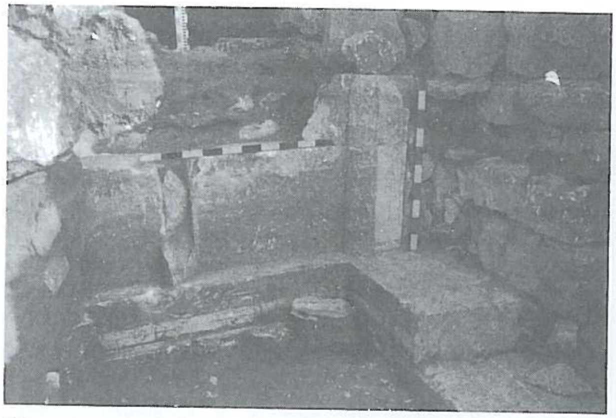
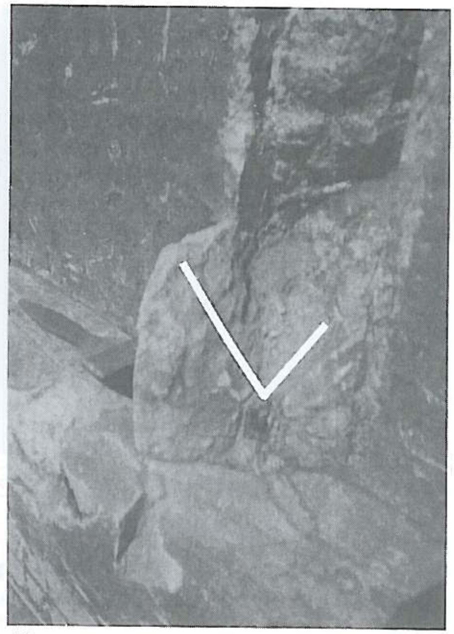


Fig. 3. Twisted block in the southwest corner of fallen tomb No. 12.



a

b



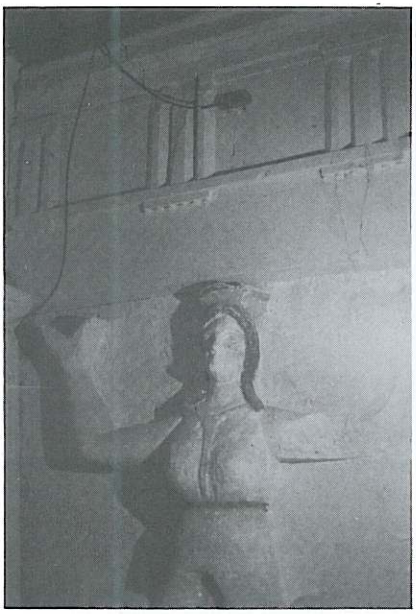
c

Fig. 4a-c. The wall that remained in the northwest part of tomb No. 30 (a), with the restored part of the tumulus embankment showing the ground with different structure on the left side of the photo (b), and detail of the column showing the conical «milonitic structure» starting from its basal iron brace (c).

remained in this part also denote that they had been subjected to a strong vertical pressure (fig. 4a-c).

The remaining two tombs, which have been completely preserved, bear traces of block shifting, cracks and shock deformations, which occurred after the tombs had been built, very often with similar orientations to the ones observed in the tombs previously described. Displacements of the blocks of the walls and fissures up to 1.2 cm in width, actually in monitoring, are observed in the tomb below the Ginina Mogila mound (fig. 5a,b). On the southwest wall of the lateral chamber of this tomb there are not only horizontal displacements of the blocks bordering the window at the entrance, but also a twisting of the blocks of the lateral walls and the upper beam of the window (fig. 6). Shifting of the blocks of the walls in a southern direction is seen on both transverse walls of the lateral chamber. In the central burial chamber the column in the southeast corner is broken at the base, similar to the columns in tomb No. 30. Fissures and displacements are also visible on the vault of the tomb.

The situation is similar in the tomb below tumulus No. 13. Apart from the displacements reaching up to 2.2 cm, much of the blocks show symmetrical and systematic flaking as a consequence of a sudden high vertical pressure



a

b

Fig. 5a,b. Open fissures in monitoring by vibrating-wire sensors (a) and other serious damage (b) in the tomb inside Ginina Mogila (UNESCO National Monument).

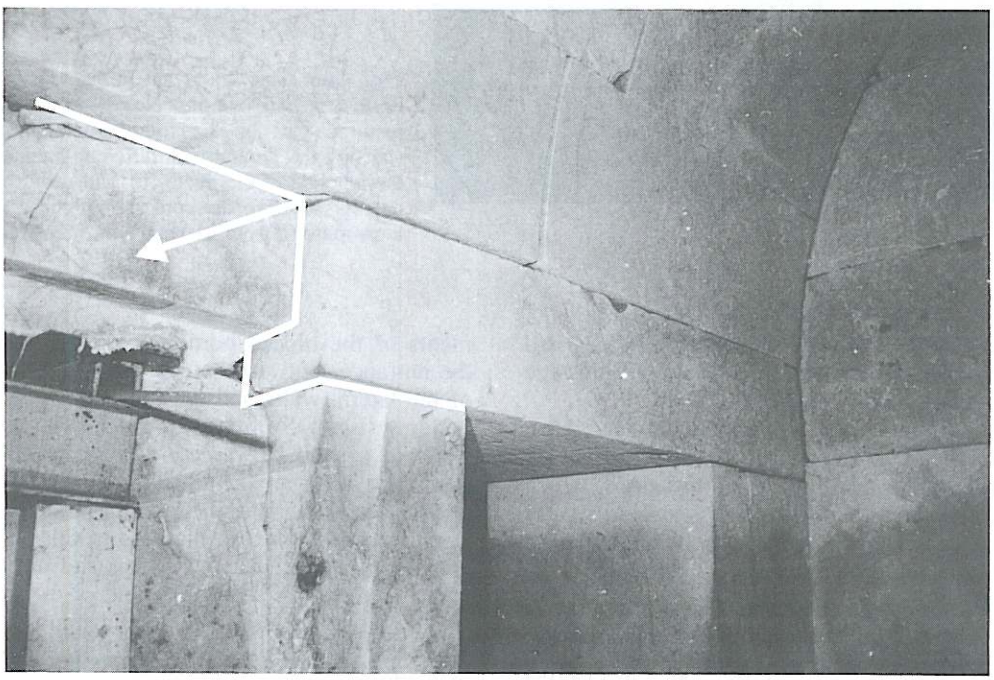


Fig. 6. Horizontal twisting of the upper beam of the window in the lateral wall of the tomb inside Ginina Mogila.

Fig. 7. Flaking of stone blocks as a consequence of the high vertical pressure that they had undergone in tomb No. 13.

(fig. 7). The eastern pilaster at the entrance to the burial chamber of this tomb shows that an iron brace had been pulled out of place by horizontal strength (fig. 8).

Irrespective of the high degree of stability of this type of tumular construction, the stone structures below them have undergone considerable deformations and destruction (table II). Of particular interest is the degree of destruction observed in the four tumuli, in spite of the similarity in their construction and similar orientation, as well as in their geological and geotechnical settlement conditions.

4. Conclusions

It is evident that earthquakes were the main cause of the damage observed in the tomb stone structures: fissures, block flaking, breaking off of stone fragments, falling of individual blocks and horizontal displacement of the blocks with opening of vertical fissures between them. The explanation for the different degree of destruction in the tombs of the necropolis are to be sought in the following:

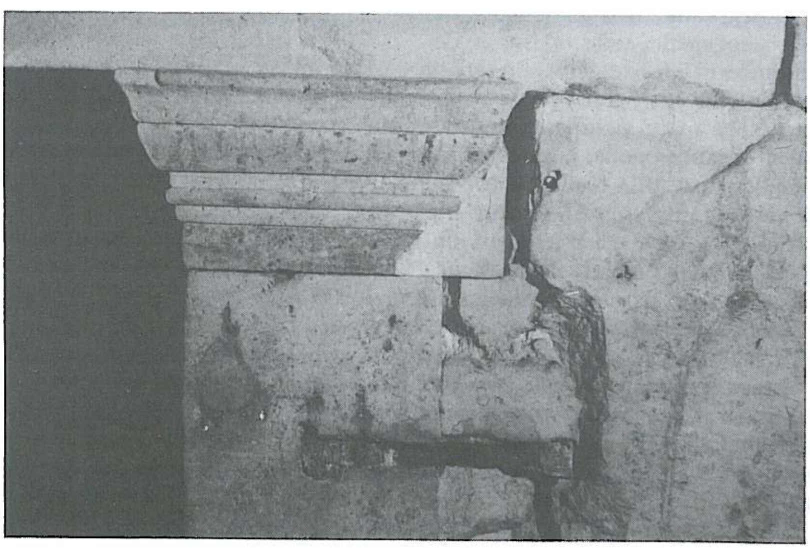


Fig. 8. Eastern pilaster at the entrance of tomb No. 13. The iron brace had been pulled out of place by horizontal strength.

Table II. The most important damage in the discovered tombs at the Sveshtari Necropolis.

Tumulus	Degree of destruction	Types of destruction and deformations
Ginina Mogila	Preserved construction with considerable damage	Fissures, individual blocks fallen, rocks flaking, breaking off, horizontally displaced blocks
Tumulus 30	Completely destroyed	Semi-preserved posterior wall
Tumulus 12	Completely destroyed	Destroyed vault, fallen lateral walls and entrance, semi-preserved posterior wall
Tumulus 13	Preserved construction with considerable damage	Fissures, rocks flaking, horizontal displacement of the blocks

– tumuli No. 12 and 30 were the earliest and they had been destroyed before the other two tumuli were erected;

– the area of the necropolis was subjected in the past to a very strong seismic event, not comparable with the ones ensuing, which produced different macroseismic effects by the small but significant local change in tumulus structure and geological conditions.

In any case, the fall of the extremely damaged tombs in the Ginina Mogila and in tumulus No. 13, denotes a good resistence of the complex tomb-tumulus to normal seismic activity, and especially to the horizontal strength that conspicuously came into play from the Roumanian seismogenetic areas. Also, it denotes the existence of an exceptionally strong seismic event in the past, not far from the necropolis area. The more significant destruction observed in the necropolis, corresponding to intensity higher than VIII could have been caused only by nearby seismic foci, *e.g.* Doulovo, Razgrad or some other location, unknown for the time being. In fact the existence of a dense network of fissures in the stone block, as well as the flaking along their edges demonstrates the existence of a considerable pressure. It is also important to note that the longitudinal axes of the tombs are perpendicular to the structural line (NW-SE) that generates the most important and nearest foci. This condition has been the cause of the observed spatial distribution of their fissures.

The difference found between the observed and the predicted intensity at that locus (degree VI-VII MSK), on the one hand, and the intensity deduced from the effects in the tumuli, on the other (higher than degree VIII), suggests that in historical times, probably – on the basis of archaeological observations – about 2300-2350 years ago and at the time of the end of Bizone (Guidoboni, 1989), the site was exposed to the impact of an earthquake more intensive than others have been in the last millennia.

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