

# Traces of seismic effects on archaeological sites in Bulgaria

Liudmil Christoskov<sup>(1)</sup>, Diana Gergova<sup>(2)</sup>, Ilija Iliev<sup>(3)</sup> and Vincenzo Rizzo<sup>(4)</sup>

<sup>(1)</sup> Geophysical Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria

<sup>(2)</sup> Archaeological Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria

<sup>(3)</sup> Geotechnical Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria

<sup>(4)</sup> C.N.R.-I.R.P.I., Roges di Rende, Cosenza, Italy

## Abstract

During the last hundred years, the period of instrumental recording of earthquakes, there has been a high seismic activity in the territory of Bulgaria. There are reasons to believe that similar activity had been demonstrated during the historical and geological periods. This is retrieved by the traces on archaeological monuments and their geological surrounding, left by violent earthquakes. The present article considers examples of destruction and deformations on sites dating from different historical periods, Thracian tumuli and dwellings, antique and medieval as well as from the time of the Renaissance. There is an area of common interest involving problems that can be solved by mutual co-operation. The findings of such studies could be beneficial to all three sciences.

**Key words** Bulgaria – paleoseismicity – archaeology – geomorphology

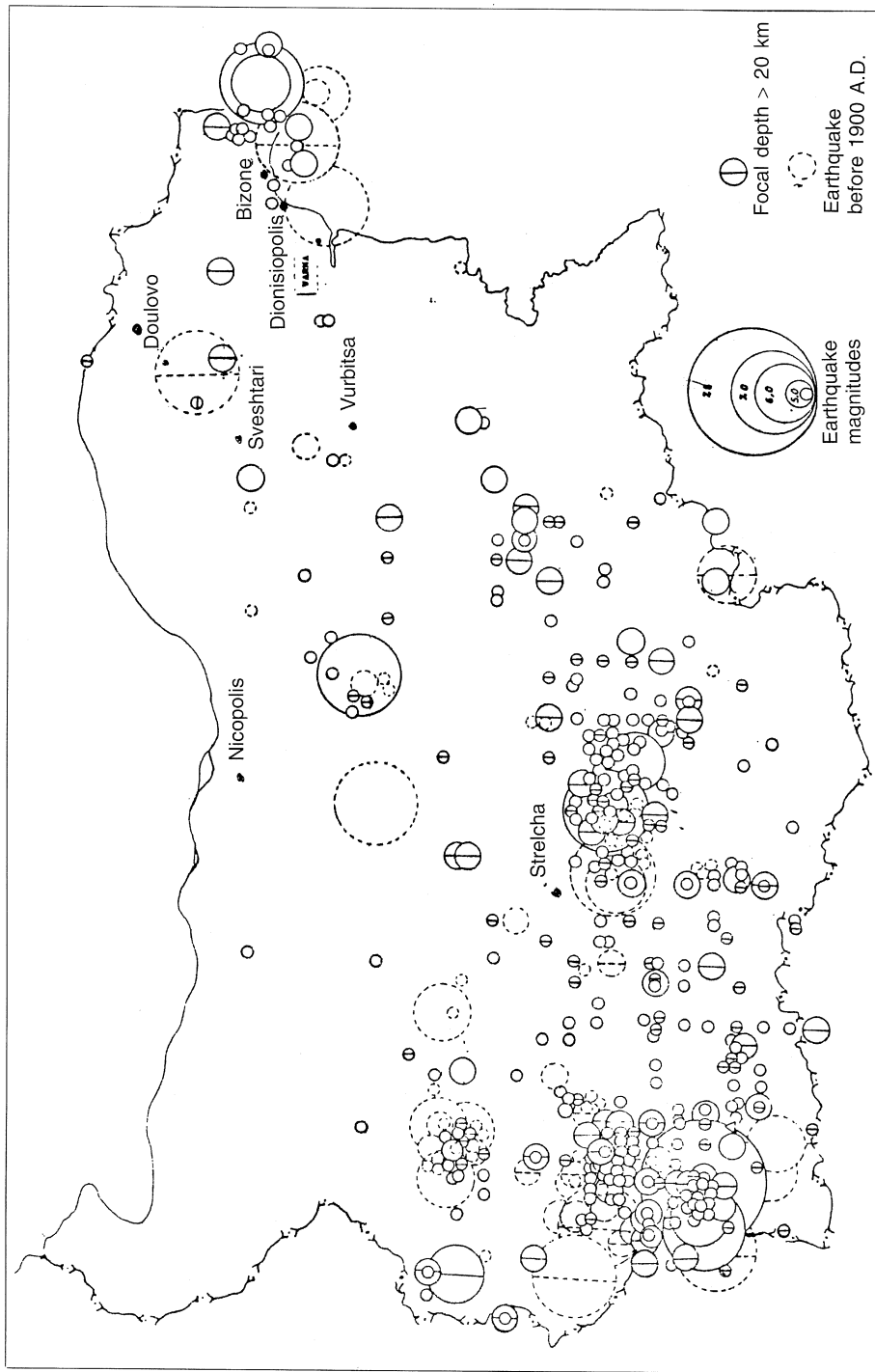
## 1. Introduction

### 1.1. Modern and ancient seismicity in Bulgaria

The territory of Bulgaria as a part of the Balkan Peninsula is in a complex geodynamic situation. More than 60 types of destructive processes on Earth have influenced the material culture and the living environment of society. Earthquakes are among the phenomena with the most significant consequences throughout the entire territory of Bulgaria, because the Balkan Peninsula is one of the most seismically active areas in Europe. Earthquakes have been known here since remotest antiquity, the most ancient earthquake being dated to the

20th century B.C. (Catalogue of Earthquakes, 1974). The natural geographic locations of the country's territory suggest that strong earthquakes were observed and have been caused by local factors both within the limits of present-day Bulgaria and in neighbouring territories. This means that in order to assess objectively the historical and the present seismic activity in the region, it is necessary to consider the entire central part of the Balkans, *i.e.* an area that is approximately four times larger than the size of Bulgaria today.

The historical part of the catalogue of earthquakes in Bulgaria and the neighbouring lands (Catalogue of Earthquakes, 1974; Grigorova and Christoskov, 1974) (Central Balkan Peninsula) covers a total of 175 earthquakes for the period from 479 B.C. until 1891, the earliest documented local earthquake being from the 1st century B.C. in the region of the town of Kavarna (ancient Bizone) on the Black Sea. It is believed that for strong earthquakes with a



**Fig. 1.** Epicentral map of Bulgaria (events from 50 B.C. to 1980 A.D.). The Doulovo source area is localised in the northern and central part of the country.

magnitude  $M > 7$  this catalogue is representative since the beginning of our era, for the magnitude interval  $M = 6-7$  – since the 4th century, and for  $M = 5-6$  documented at present – after the 10th century. In practice, these are the earthquakes which may have caused damage and destruction to archaeological monuments and buildings. The evaluation of the seismic activity involves a number of specific research areas related to the detection investigation and analysis of historical evidence and documents (Christoskov, 1987). Contemporary and historical seismic activity for the period after 50 B.C. is reflected on the map of the epicentres, and the most probable distribution of the seismic source zones of the strong earthquakes on the country's territory is given also in fig. 1. For the moment, these maps are the only sources of background information about the distribution of the seismic activity in the territory of the country.

### 1.2. *Ancient remains as potential sources of seismic information*

The only sources of background information about the seismic activity in the country during the early historical periods for which historical evidence is scarce or lacking altogether, can be found in the traces of that activity on archaeological monuments and their geological environment. This type of source data can be supplemented both by studying newly-discovered monuments and by reinterpretation of known ones. The possibilities of using the archaeological source basis depend both on the character of individual categories of archaeological sites and on the subjective interest of researchers. The Bulgarian lands during the 1st millennium B.C., to which the earliest evidence has been dated, are characterised by the domination of tumuli containing impressive stone tombs, whereas the settlements and the urban centres have been less investigated and seldom had more massive construction in them. Joint archaeological, seismological studies on archaeological monuments and their environment, on the deformations and reconstruction with a view to reconstructing earlier historical or nat-

ural processes, are of equal importance for completing the database on the country's seismic activity, as well as in connection with the more correct interpretation of historical events, and – last but not least – for solving the problems of the protection of the archaeological heritage.

The principle of co-operation and mutual control on the observations of individual specialists in palaeoseismic studies guarantees the maximum objectivity of the scientific conclusions. In this connection, it would be expedient for all evaluations of damage and destruction in archaeological monuments and sites to take into account the observed and the predicted fields of the seismic activity in the country (fig.1), together with the geological conditions. These fields are the most probable areas, as location and intensity of the earthquakes, which can, or rather which could have caused the destruction of certain archaeological monuments, depending on their distance from the seismic sources. Among the numerous archaeological sites in Bulgaria bearing traces of seismic impacts, the present study presents only some cases in which it was possible to engage in more in-depth studies and to extract new data in the sphere of palaeoseismic studies.

## 2. **Vaulted graves at Sveshtari and Vurbitsa**

### 2.1. *General information*

Data on possible seismic manifestations, known from the Late Iron Age by the destruction observed in the tumuli containing tombs near the village of Sveshtari (Gergova *et al.*, 1993), can be further expanded by the observations on the tomb under a tumulus near the village of Vurbitsa, dated to the 5th-4th century B.C. (excavation of G. Atanasov) and located about 80 km to the South.

The region in which the tumuli near Sveshtari and Vurbitsa are located forms a part of the hilly Danubian Plain, built of Lower Cretaceous karstified and fissured limestone, covered by about 10-30 m thick loess sediments. The limestone and the loess contrast



(a)



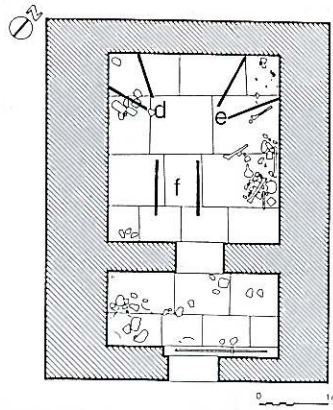
(c)



(b)

**Fig. 2a-f.** Tombs near the village of Vurbitsa (5th-4th century B.C.) and in the Sveshtari Necropolis (2nd half of 4th and the beginning of the 3rd century B.C.). a-c) The tomb in Vurbitsa bears traces of a weaker seismic impact with respect to the ones observed at Sveshtari necropolis (about 80 km nearest to Doulovo scismogenic area). In this tomb one observes only block displacement; no flaking, no breaking off, no destruction. At the top of fig. 2d-f: a plan of preserved tomb No. 13 at Sveshtari (the least damaged among the ones already excavated in this funerary complex), from the point of view of photos 2d, 2e and 2f. d, e) Symmetrical flaking of the roof blocks and lateral opening of the chamber (see arrows), both due to the born high vertical pressure. f) Opening of the blocks in the roof of the same tomb forecast its fall.

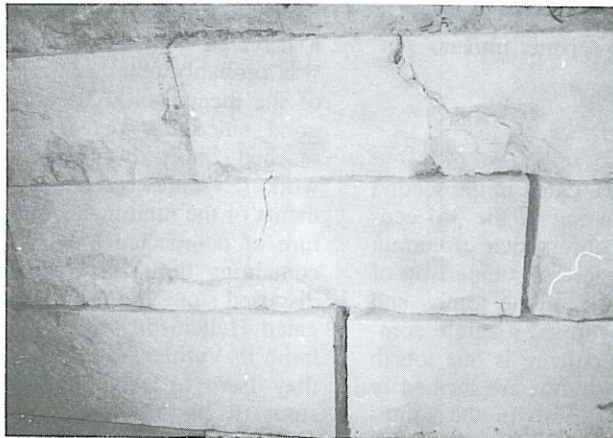




d



e



f



**Fig. 2g.** The tomb under tumulus No. 12 at Sveshtari, that were completely destroyed with a semi-preserved posterior wall.

sharply in their physico-mechanical properties including acoustic stiffness, forming a two-layer geomechanical model of the terrain on which the tumuli have been built. With such a geological structure and relatively flat relief, the deformations of the construction and of the surrounding terrain may be caused by sinking of the loess produced by seismic impacts.

## 2.2. Description of the graves

The tumuli in Sveshtari, dated in the second half of 4th and the beginning of the 3rd century B.C., were built in observance of certain ritual construction principles. A comparison of the proportions of the size of the tombs and mounds shows that they formed a single complex: the length of the sepulchre is one fourth of the tumuli radius. The tombs are located in the third quarter of that length in the south-

eastern parts of the mounds (Gergova, 1992). The shape of the tumuli containing the damaged and studied tombs at Sveshtari and Vurbitsa, is pseudo-conical with an elliptical base and main axis oriented NW/SE (as a large part of the Bulgarian tumuli), with a height ranging between 6 and 17 m. The tumuli were built on a layer of well compacted grey clay, which was probably obtained from the leached layer of the recent soils. The compaction was very good since dry density (1.90 g/cc) can be reached only after considerable compaction work (Evstatiev *et al.*, 1993). The embankments of the tumuli show an interlayered structure of compacted loess and clay, sometimes containing thin layers obtained by accurately disposed stone flat fragments. The four investigated Hellenistic tombs in Sveshtari and the tomb in Vurbitsa are similar in shape and size; they have a rectangular plan, small dimensions (6-20 m<sup>2</sup>) and a semi-cylindrical vault

(figs. 2a-g). The thickness of the walls is about 0.50 m for the transverse wall and it ranges between 0.80 and 1.50 m for the longitudinal ones (Gergova *et al.*, 1993). The tombs in Sveshtari are built of limestone blocks arranged in two vertical rows, with a filling of crushed stones of the same material; the tomb in Vurbitsa is built of sandstone blocks that are surrounded by a lens of fluvial pebbles, coming relatively far from the site and constituted by the same arenaceous material. The tomb blocks are well or rough finished only in their internal faces.

### 2.3. Deformation of graves

Of the four investigated tombs in Sveshtari two proved to be strongly deformed and the other two almost entirely destroyed. Tomb No. 12 in Sveshtari was discovered to have a destroyed vault with the part facing the north-western lunette and two parallel blocks from the south-western corner having fallen in (fig. 2g). The fallen stone blocks were cleared away, and the tumulus above it was restored again in the destroyed part. In tumulus No. 30 only part of the walls has been preserved; the conical fissures on half a remaining column suggest that they had been subjected to strong vertical pressure. The other remaining two investigated tombs in Sveshtari, that have been completely preserved, show large deformations, in horizontal block shifting, twisting, cracks and shock-type deformation, symmetrical and systematic flaking of the vault-blocks as unambiguous consequences of a sudden high vertical pressure (Gergova *et al.*, 1993) (fig. 2d-f). Similarly, the tomb in Vurbitsa shows light displacements and twisting of blocks, at the entrance and in the first chamber (fig. 2a-c).

The restoration of the tumular embankments, after the ruins of the destroyed tombs have been cleared and the existence of reinforcing braces in one of them, suggest that the hypothetical proposed earthquake took place soon after they were built, or even at the time

when some of them were still open for certain rites to be performed in them.

The possible causes of all observed deformation are, theoretically, the natural ageing of the limestone, possible settling of the ground-basement and seismic impacts. Nevertheless, looking at the characteristics of the observed deformation that denote significant horizontal stress and sudden high pressure, we have to assume a different rule for the above hypothetical causes, attributing to the seismic impacts the main visible effects and damage and to the other destabilizing factors only a secondary importance.

## 3. Chirakman Cape - The ancient city of Bizone

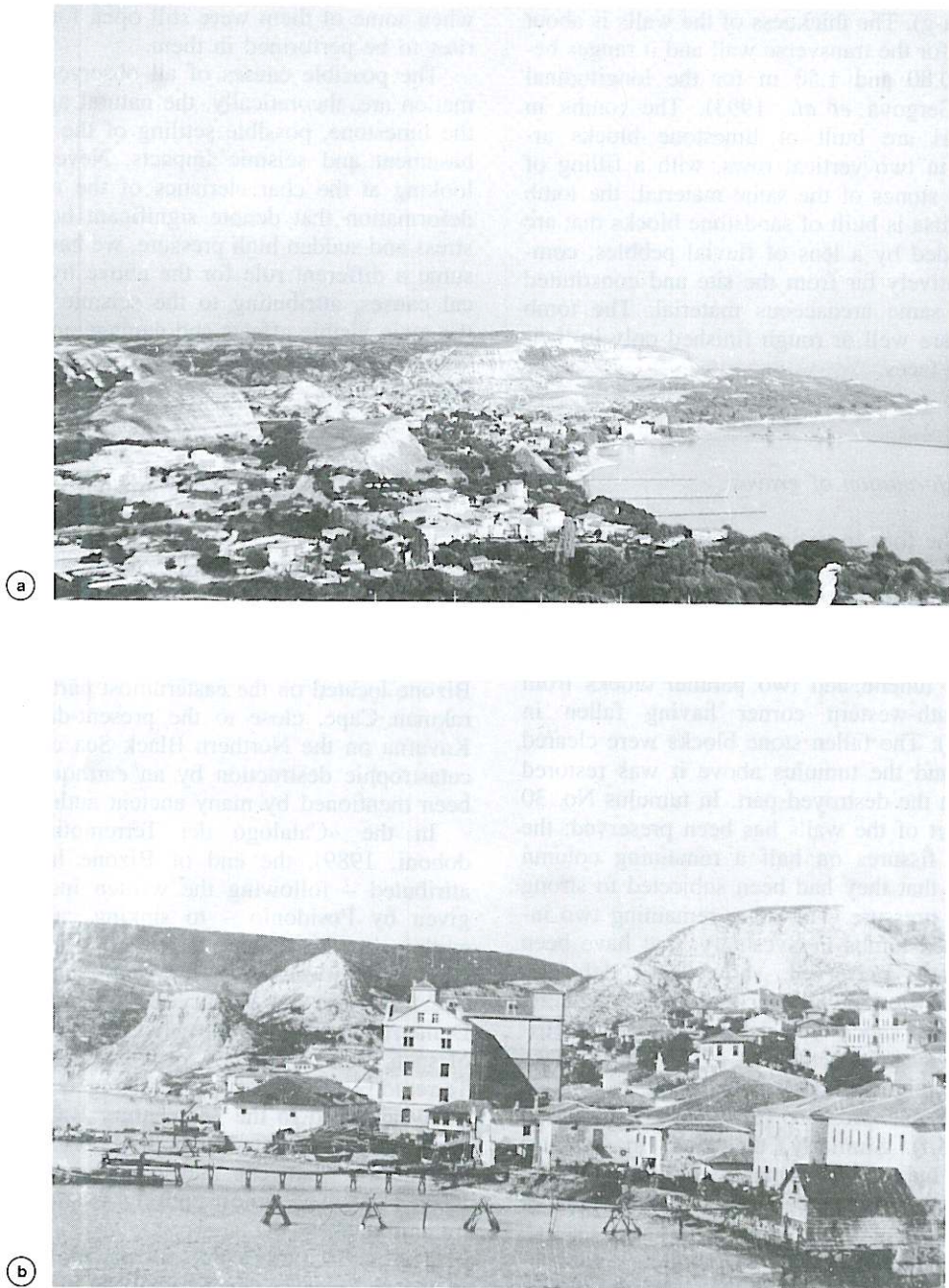
### 3.1. Destruction of the city

Among the few Thracian centres investigated, special interest is aroused by the city of Bizone located on the easternmost part of Chirakman Cape, close to the present-day town Kavarna on the Northern Black Sea coast. Its catastrophic destruction by an earthquake has been mentioned by many ancient authors.

In the «Catalogo dei Terremoti» (Guidoboni, 1989), the end of Bizone has been attributed – following the written indications given by Posidonio – to sinking caused by earthquake; this sinking happened in an uncertain age, between the Bura earthquake (373 B.C.) and the 1st century B.C. (the time of Demetrio di Callatis who gave the information of such event to Strabo). In the «Catalogo dei Terremoti» the date of the sinking is orientatively assigned to the 3rd century B.C. In the same book the sentence of Strabo is reported as follows: «between and Apollonia there is Bizone that was almost entirely swallowed up by earthquakes».

The actual observation on the morphology of the site clearly denotes that the end of the city was caused by a fall-type landslide, sunk in the sea. On the basis of archaeological data collected in Bulgaria the abandonment of the ancient city dates back to the 1st century.





**Fig. 3a,b.** The town of Balchik (ancient Dionisiopolis) built on an inter-layered system with dominant limestone in the upper part, over a sequence of marly and clayey levels at the base. The massif is affected by serious slidings, susceptible to remobilization by seismic shock and today showing a continuous creep activity. a) View of the coast north of Balchik.



### 3.2. Physiography and geology of the area

The tall Chirakman Cape rises 120 m above sea level in its eastern part. It is built entirely of middle Sarmatian horizontal layers. As a mechanical model, this is a stratified sandwich-type system, consisting of white, porous, soft, marly limestone, intercalated by relatively hard and fractured limestone, less frequently by clayey layers. Marly limestone predominates in the visible part of the profile above the level of the sea. It has a low volume density of  $1.30 \times 10^4 \text{ n/m}^3$  and high porosity up to 54%. Its cohesion is  $8 \times 10^5 \text{ N/m}^2$ , the angle of internal friction is  $30^\circ$  and the velocity of the longitudinal waves 1400 m/s. With such parameters, this massif has a low wave resistance, high brittleness, and is hence susceptible to destruction and deformations caused by seismic shocks (figs. 3a,b and 4a), all the more that ground and underground waters, where existing, also have a strong negative influence on the physico-mechanical properties of rocks of this type.

### 3.3. Landslides

Geological and archaeological research has shown that Bizone was located at the end of Chirakman Cape, where ceramic fragments are found to this day. The southern part of the Cape collapsed, together with a part of the city, and sank into the sea, where ceramic fragments, remnants of walls, etc. have been found, chaotically mixed with rock masses below sea level (figs. 4b,c).

The morphology of Chirakman Cape on the sea front side denotes an evolution by falls, whose cause is in relation to the combined action of seismic activity and sea abrasion. Previous studies have pointed out the rule of seismic shock on the landslide mobilisation in this area, where – from a geotechnical point of view – the outcroppings are constituted by brittle materials (Evstatiev and Rizzo, 1984; Kamenov *et al.*, 1972). As a recent example we recall the landslide of Momcil, about 15 km south-western from the site), caused by a fall following the earthquake at the beginning of

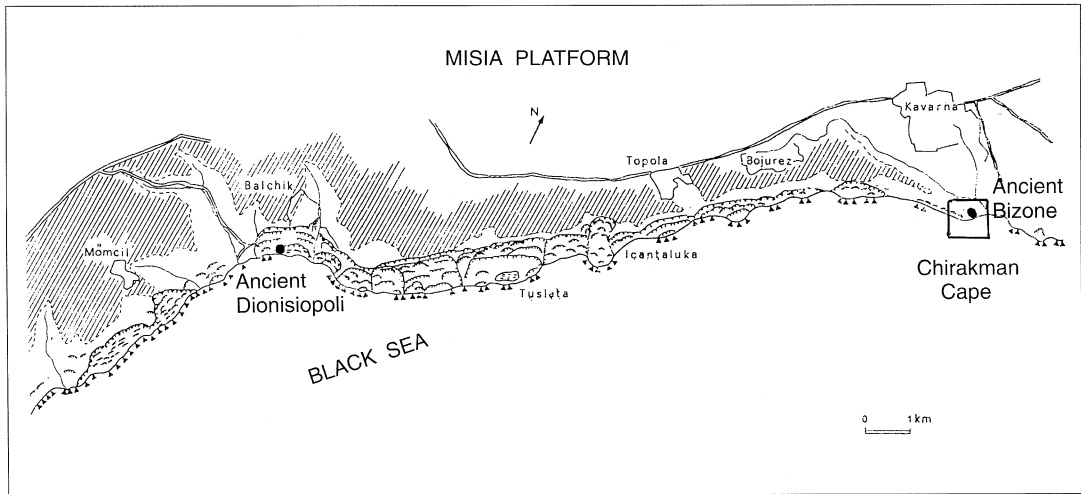
this century, that moved down, in a similar slope, about 20 million cubic meters (Evstatiev and Rizzo, 1984) (fig. 4a).

The result of seismic activity can still be seen in the frontal part of the cape, towards the sea, by the open fissures running parallel to the angle of the front of the cape, where we can observe recurrent slidings below them. The landslide-bodies at the base of Chirakman Cape have been destroyed by abrasion; they have been preserved in the lateral side, where one can observe the rounded relief typical of this material. The landslide that tore off the frontal part of the cape so that it fell in the direction of the valley and in the present-day harbour (the right side in figs. 4b,c), is of great interest. The terrain has been subsequently stabilised and new industrial buildings were later erected there. By causing abrasion of the shore, the sea has exposed the transverse profile of the landslide and it is possible to see the typical landslide elements, destroyed rock blocks, sloping layers, disturbed zones, a steep sliding surface which distinguishes the immobile massif with horizontal layers from the strongly disturbed landslide body.

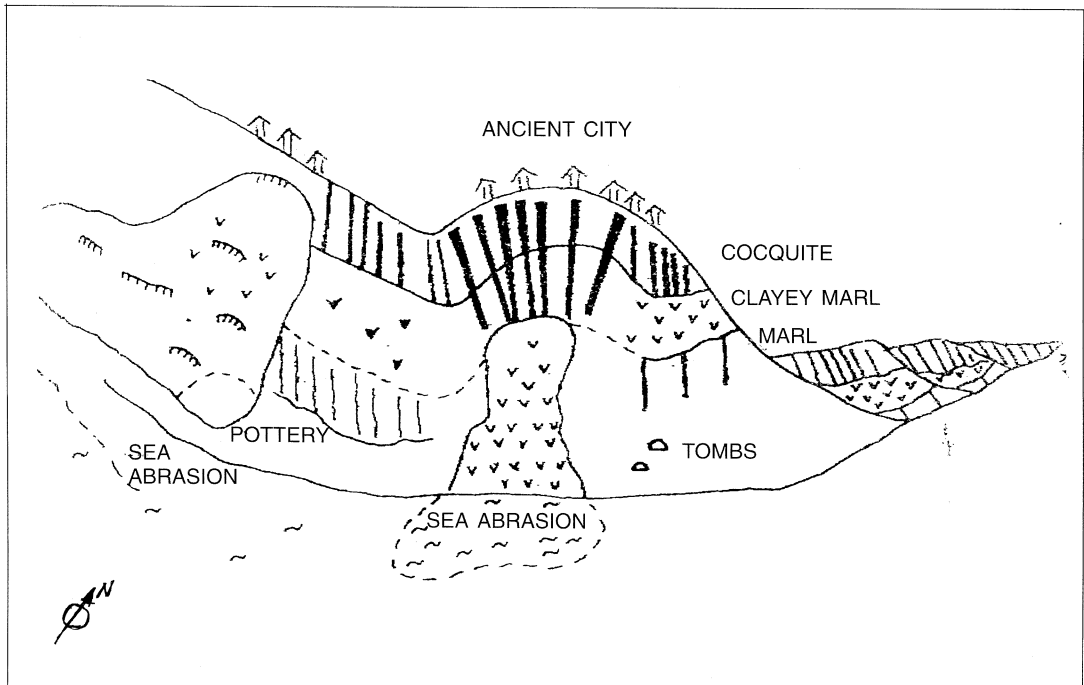
## 4. Discussion

From the maps of the epicentres and the focal zones (fig. 1), it can be seen that the Doulovo seismic source zone is the closest one to the two investigated vaulted grave sites; Sveshtari is localised in immediate proximity to the western end of that zone, while Bizone is localised near another closest seismogenic area.

The damage and destruction in Sveshtari bear traces of strong impacts (displacements of heavy stone blocks, fissures in them, collapsed vaults, etc.) (figs. 2d-g); while the effects near Vurbitsa, 80 km to the South, are weaker, probably by one intensity degree according to MSK macroseismic scale, hence they can be associated with longer-lasting impacts (open joints in the construction elements, displacement of blocks, rare appearance of cracks, no collapsed roofs) (fig. 2a-c). This picture suggests that the damage and destruction of two

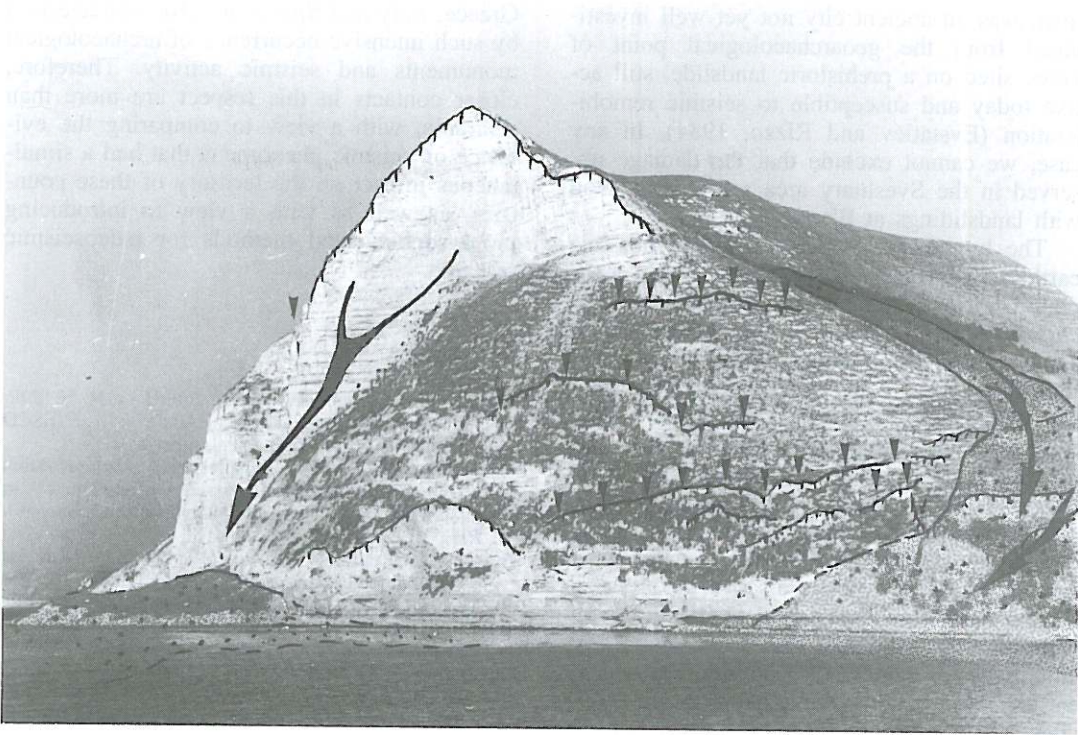


a



b

**Fig. 4a,b.** The Black Sea Coast near Chirakman Cape. a) Geomorphology of the Coast between Balchik and Kavarna, at the border of Misia Platform, showing wide spreading of landslides and related sea erosion (marked by triangles) (from Kamenov *et al.*, 1972; modified by Evtatiev and Rizzo, 1984). b) Geomorphological sketch showing the landslides that destroyed the Cape and the ancient town of Bizone during an earthquake (within the second half of 4th and 1st century B.C.).



**Fig. 4c.** The Black Sea Coast near Chirakman Cape. Current view of Chirakman Cape showing recent cracks (arrows) and remains of the ancient landslide-bodies containing archaeological fragments (dotted area; the big arrow shows the probable provenience of the slided material that involved the ancient town of Bizone).

archaeological sites were caused by one and the same earthquake, most probably coming from the Doulovo source area, bearing in mind that the zone can generate earthquakes with a magnitude of up to  $M = 7.5$  of the Richter scale. This means that Sveshtari earthquake (approximately  $M = 7.0$ ) can prove to have been of an intensity 9 (MSK scale) and even higher on the earth's surface (40-55 km radius for intensity 9), Vurbitsa being of intensity 8 (65-100 km radius). We have also taken into account the fact that both archaeological finds belong to the category of underground archaeological sites, hence the impacts on them would have been weaker than the on anything built overground, which lends support to the hypothesis of the proximity to the source of seismic waves.

Attributing the destruction in both sites to the same earthquake could also be supported by the fact that the average – and hence the most probable – interval between two earthquakes of a similar intensity, in our opinion, exceeds 300 years, which is beyond the chronological framework within which the cited archaeological sites are examined.

The coincidence between historical evidence on the fate of Bizone and current geomorphological observation of that place (fig. 4b,c) suggests that the destruction of a large part of the cape in a southern and eastern direction caused by massive landslides was induced by strong earthquakes, in a period between the 1st and the 4th century B.C. During the same events the town of Dionisiopolis (modern Balchik) was probably damaged. This last



town was an ancient city not yet well investigated from the geoarchaeological point of view, sited on a prehistoric landslide, still active today and susceptible to seismic remobilization (Evstatiev and Rizzo, 1984). In any case, we cannot exclude that the damage observed in the Sveshtary area might be related with landslidings at Bizone.

The hypothesis launched about a possible earthquake in the Doulovo seismic zone in the period between the 5th and 3rd century B.C. cannot be verified through other archaeological sources for the time being, because no archaeological evidence dated to that period has been discovered yet. This does not mean that there were no such events, but rather that there are no data or observations for their reliable documentation. In the course of future studies in the region of north-eastern Bulgaria (100 km radius around Sveshtari) it would be particularly important for the newly-discovered archaeological sites from that period to be very carefully investigated with a view to detecting possible traces of damage or destruction caused by earthquakes. Among the other archaeological sites which currently provide information on seismic impacts, but still require more detailed exploration, one should also mention the Thracian tomb near Strelcha in Southern Bulgaria (excavation of G. Kitov), the Roman towns of Novae Nicopolis at Istrum in Northern Bulgaria, as well as the Termae of Nicopolis at Nestum, along the Mesta River, in Southern Bulgaria, destroyed by an earthquake in the beginning of the 4th century A.D., which affected other urban centres of the Macedonian province as well.

The examples cited above, as well as the archaeological sites marked for further more detailed observations and research, suggest the importance of joint studies, uniting the potential of the three scientific domains, for reconstructing historical and natural processes in the past, for discovering phenomena that have not been familiar so far and for adding new information to the evidence contained in the written sources.

Other Mediterranean countries (Turkey,

Greece, Italy and Spain) are also characterised by such intensive occurrence of archaeological monuments and seismic activity. Therefore, closer contacts in this respect are more than desirable, with a view to comparing the evidence on seismic phenomena that had a simultaneous impact on the territory of these countries, as well as with a view to introducing more sophisticated methods for paleoseismic research.

#### REFERENCES

- Catalogue of Earthquakes* (1974): Edited by N. V. SHEBALIN, V. KARNIK and D. HADZIEVSKI, UNESCO Surv. Seism. Balc. Reg. Skopje, part I, II.
- CHRISTOSKOV, L. (1987): Seismological characterization of the area connected with a series of earthquakes in 1986 in the area of Gorna Oryahovitsa, *Bulg. Geophys. Rev.*, **13**, 1-76 (in Bulgarian).
- EVSTATIEV, D. and V. RIZZO (1984): Sull'origine ed evoluzione delle frane nella zona di Balchik, sul Mar Nero (Bulgaria), *Geol. Appl. Idrogeol.*, **19**, 289-305. Geological Map of Bulgaria, 1:500000, edited by G. CHESHITEV and I. KUNCHEV, KGMR, Sofia, 1989.
- EVSTATIEV, D., D. GERGOVA and V. RIZZO (1993): Structural and geotechnical observations on tumuli in Bulgaria and some aspects of the burial rites in Hellenistic Thrace, in *Proceedings of the International Conference on «Geoarchaeology of Tumuli in Ancient Europe – 1st mill. B.C. - 1st mill. A.C.»*, Cosenza, Italy, 16-19 June 1993, PACT-network series, Brussels, No. 48.
- GERGOVA, D. (1992): The problem of the plundered Thracian tombs and a method applied for its solution, in *100 Jahre nach Schliemanns Tod*, Berlin, edited by A. SCHLIEMANN, 283-293.
- GERGOVA, D., I. ILIEV and V. RIZZO (1993): Seismic event dated to the Hellenistic period on Thracian tombs near the village of Sveshtari (Northeastern Bulgaria), in *Proceedings of the International Conference on «Geoarchaeology of Tumuli in Ancient Europe – 1st mill. B.C. - 1st mill. A.D.»*, Cosenza, Italy, 16-19 June 1993, PACT-network series, Brussels, No. 48.
- GRIGOROVA, E. and L. CHRISTOSKOV (1974): Map of the maximum observed intensities in Bulgaria 1800-1970, in *Proceedings of the Semin. Seismotect. Map Balk. Reg.-App.: Maps, Dubrovnik, April 1975*, UNDP/ UNESCO Surv. Seism. Balk. Reg. Skopje.
- GUIDOBONI, E. (1989): Catalogo dei terremoti, in *«I terremoti prima del Mille in Italia e nell'area Mediterranea. Storia archeologia sismologia»* (SGA Editor, Bologna), p. 651.
- KAMENOV, B., A. DEMIREV, V. VUTKOV, S. TSVETKOV and E. AVRAMOVA (1972): The landslides along the Black Sea Coast, near Balchik, in *Bull. Geol. Inst., Bulg. Acad. Sci.* (in Bulgarian).