# Holocene seismodislocations of Kelmentsy part of the Dniester area, Ukraine

**Iuliia KALUSH[1] and Bogdan RIDUSH[2*]**
[1]Chernivtsy „Yurii Fedkovych" National University, Scientific Library, Ukraine
[2] Department of Physical Geography and Natural Management, Chernivtsi "Yurii Fed'kovych" National University, str. Kotsubynskogo 2, 58012, Chernivtsi, Ukraine

* Correspondence to: Bogdan Ridush, Chernivtsi "Yurii Fed'kovych" National University, str. Kotsubynskogo 2, 58012, Chernivtsi, Ukraine. E-mail: ridush@yahoo.com.


doi: 10.4316/GEOREVIEW.2013.22.1.68

GEOREVIEW

***Article history***
*Received: Dec. 2012*
*Received in revised form: Jan. 2013*
*Accepted: February 2013*
*Available online: June 2013*

**ABSTRACT:** Holocene landslide-gravitational seismodislocations in the Kelmenetsky part of the Dniester area were formed due to strong platform tremor $M_w$ >4.5, which took place in between 1.000 BC and XVI-XVII centuries. They are presented as different sizes fragments of limestone oncoid cliff.

The results of seismodislocation's measurements, mechanism and causes of their formation should be considered in seismicity of the territory to protect the environment and population from serious consequences of future earthquakes.

KEY WORDS: earthquake, Holocene, seismodislocation, seismo-gravitational collapse, Dniester.

## 1. Introduction

The seismic activity affects the formation of surface relief. Few decades ago manifestations of tremors in relief were rare considered. In recent years a lot of researchers defined seismogenic factor to be one of principal causes for surface deformation and, also, such seismogenic structure present in all seismic areas. The geological and geomorphological complexes genetically relevant for tectonics and seismic potential of a territory are called *seismodislocations*. Vakhrushev *et al.* (2001) proposed the term *seismomorphogenesis* as a process of their formation and landform transformation influenced by seismic events.

Seismodislocations formed more than one thousand years ago are called paleoseismodislocations and used in paleoseismogeological method (Solonenko, 1973). This method has great value in platform areas seismic research on platform areas, because in most cases this is the only way to check the maximum seismic activity. This type of research is the newest in Ukraine. Here we present paleoseismic investigations in the Pre-Carpathians region.

## 2. The regional geological settings

The studied area is located near the Komariv Village, to northeast of the Carpathian Basin (Fig.1). This territory is a part of the Volyn-Podollian monocline and it belongs to the conjunction zone between the East-European platform and the Carpathian Foredeep. There are many tectonic faults extending from northwest to southeast (Gerenchuk, 1978).

The basement of tectonic plate is built with Archean magmatic and metamorphic rocks, and covered with Late Proterozoic grey argillite and siltstones, Cambrian glauconitic sandstone (€), Ordovician grey or brown sandstone and limestone ($O_2$), Silurian quartzite sandstone, and greenish marl (S), Cenomanian greenish marl and glauconitic sandstone ($K_2c$) (Tsegelnuk, 1974). Neogene group ($N_1^{sm}$) is represented by Sarmatian grey marly clay and limestone oncoid (Fig. 2). Oncoid is a massive object of various forms, formed, mostly, by skeletal remains of organisms and other deposits. Sarmatian oncoids has irregular lenticular form and consist of Lithothamnium, shells of Vermetus and Ostreidae (Koroljuk, 1952).


**Figure 1**. Location of the investigated site Komariv. This figure is available in colour online at www.georeview.ro.

The Dniester River valley at this part has canyon-like morphology. The Quaternary (Q) deposits form continuous cover composed with clastic sediments. There are gravels, sands, yellow-greenish and brown clay fluvial sediments. The canyon cut into the level of 5$^{th}$ Early Pleistocene terrace. The Quaternary deposits of the 5$^{th}$ terrace of the Dniester River valley are built with reddish loam and sandy loam with total thickness of 2-3 m. The first and second Dniester terraces are below the lake level now. The 4$^{th}$ and 3$^{rd}$ terraces are absent on the site and replaced with a scarp, composed with deluvial deposits.

**Figure 2.** The view on one of the oncoid cliffs near the Dniester Lake in Komariv Village. This figure is available in colour online at www.georeview.ro.

The studied area belongs to Dniester-Pre-Carpathian seismic region, which is characterized as 6-8 points of seismic activity on the MSK-64 scale (Sagalova, 1969). This territory is under influence of the earthquakes with epicentres in the Vrancha zone in Romania. Also, because of the block structure of the East European platform, there are local epicentres, which are capable to become the reason of seismic manifestations on this area.

The tectonic features, neotectonic activity, location not far from the Vrancha zone, as well as interesting landforms and rocks are the favourable conditions for paleoseismic research.

## 3. Techniques of paleoseismological investigations

The paleoseismogeological investigations mainly conducted in mountain areas. Florensov (1960) and Solonenko (1962, 1973) were among first to propose the paleoseismogeological method and formed the techniques to detect paleoseismodislocations in Caucasus. For our researches in platform areas we transformed these techniques, according to which our paleoseismogeological study was composed of the following steps:

1. To define assumed areas with traces of strong earthquakes according to geological, geophysical and seismological data. This study bases on fault-block model of the tectonic features. This specification was carried out by comparing of the morphometric data and relief, using aerial photographs, deposits data, etc;
2. To apply the topographic, tectonic maps and geological sections and to selected location of possible seismic deformations of landforms or deposits.
3. To organize the field work directly on the studied structure.

4. To measure the size and form of violation, conditions of formation, its distribution and direction. After we determined the type of the paleoseismodislocation and suggest the size of the earthquake and its impact for the surrounding landscape.
5. The important step in paleoseismological investigation is to search the records for paleoseismodislocation dating.
6. To research related (secondary) deformations.
7. To date the paleoseismic events, to calculate the relative and numerical ages, which allows to determine the time of the earthquake.

It should be noted that to choice methods of paleoseismogeological investigations depends from type of study object, as well as ecological and geomorphological features of the study area.

## 4. Paleoseismodislocation's characteristics

The Komariv paleoseismodislocations are the Sarmatian limestone blocks of different size, which formed seismic-gravitational deposits. They extend for about 1 $km^2$ northeast of the Komariv Village, 230 m far from the Dniester Lake. Studied objects are rock fragments that composed low limestone cliff in the past. Commonly, this collapse could be formed by gravitational processes, but an impressive sizes and uniformity surfaces of the preserved part of cliff and blocks evidence it seismic origin. The cliff is built with detritus organogenic limestone, which is divided into two beds divided by a thin (3-4 cm) interlayer of bentonite clay. The bentonite clay has good catalytic activity, astringent and gluing properties, so that's why, in contact with water it becomes slippery. During powerful seismic manifestations, the limestone blocks of the upper bed slided on the clay layer surface, and after turned over and shifted downslope. At the foot of most blocks we observed intensive local traces of karst, caused by waterproof bentonite clay. When seismic waves pass through different type of sediments, diffraction, interference, different amplitude oscillations are created. These factors decrease the stability of slopes. The earthquake size more than 7 points leads the emergence of slope gravitational processes. That's why the studied collapse we call seismic-gravitational collapse.

For our investigation we chose 14 the largest fragments in different places of the area, measured their sizes, angle of incidence and distance from the cliffs. The measurement results are shown in Tab.1. We performed measures from the bases of cliff “I” and “II” (Fig. 3).

The point "I" is limestone cliff with carved images of mythical creatures (Artukh et al., 1997). There is a limestone block with carved in sacrificial-bowl, which is similar with Early Iron artefact in Perperikon (East Rhodopes, Bulgaria), was found near the cliff. The altar-bowl in Komariv is a recess in form of an inverted trihedral pyramid. After the studying of the block's foot, we founded its initial location on the cliff. This fragment split from the rock, turned out and fell under the influence of powerful seismic shock.

Fragments N 1-7 have morphological affinity with cliff surface and joint trajectory. Block №4 is the largest and it situated 30 m far from site “I”. It is proof of a strong seismic manifestation. The most interesting block is N 7. There are many questions about reasons and conditions of its location. The eastern side looks like foot (it's different as in other blocks). The block consists of seven parts, four of them are larger and three are small. There is a niche 60 cm in diameter in the centre of this block. Originally it's natural blowing niche with traces of artificial cutting. The crosses of different forms are carved on the niche's walls. A bilateral cave monastery complex existed on the both sides of the Dniester River, in Bakota and Komariv. This complex is dated not later than 17th century (Ridush, 2008). Obviously, the crosses carvings in niche were connected with the monastery. It means that seismic dislocations were formed between 3.000 and 300 years ago, and there are the Holocene seismic dislocations. But this dating is wide and needs refinement using absolute dating techniques (Fig. 4).

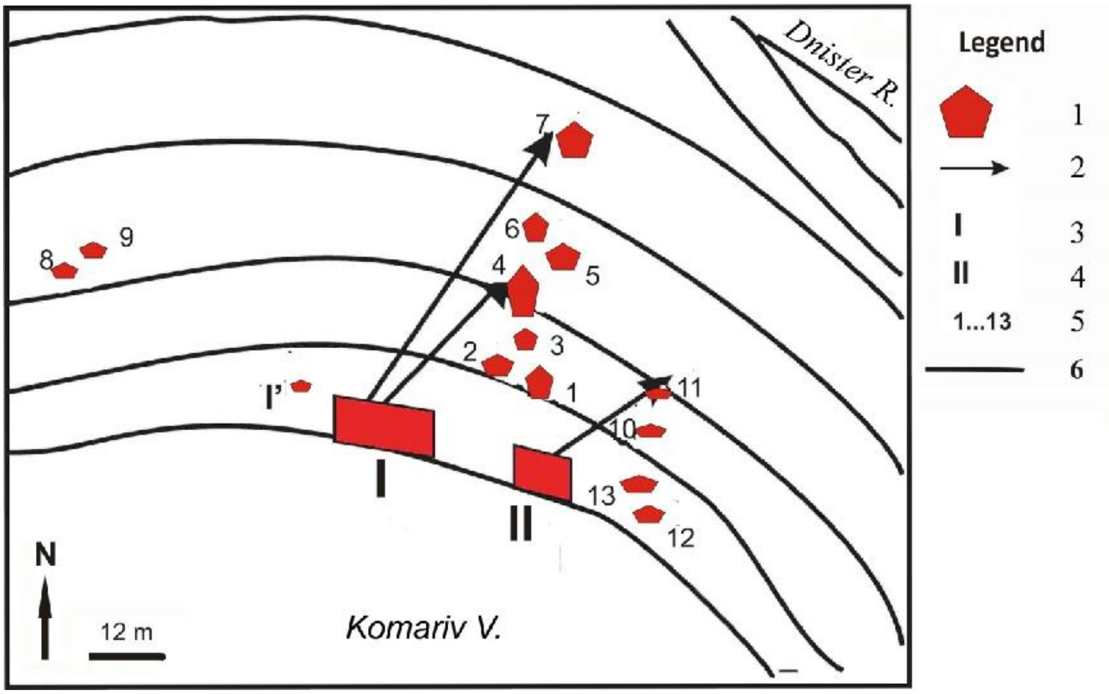


**Figure 3.** Scheme of the Komariv paleoseismic dislocation. Legend: 1 - paleoseismic dislocations; 2 - direction of block movement; 3 - the cliff “I” with ancient bas-relief; 4 - the cliff “II”; 5 - dislocated limestone blocks; 6 - contour lines, 10 m. This figure is available in colour online at www.georeview.ro.


A B

**Figure 4.** Cave cell (A) and the foot (B) of block № 7. This figure is available in colour online at www.georeview.ro.

The blocks N 8, 9 are localized in the western part of studied site, and the blocks N10, №11, №12, №13 in the eastern part. They are located in almost a straight line, because they moved concurrent and gradual during the falling. Southeast from “I” on the distance 15 m we studied another limestone outcrops “II”. We suppose that in the past cliffs “I” and “II” were one, but now they are separated.

**Table 1.** The approximate size of rock blocks and vectors of their movement downslope (fig. 3)

| NN of fragment | Width, *b*, m | Height, *h*, m | Distance*, *l*, m | Azimuth, *α*° |
|---|---|---|---|---|
| **I** | 6.10 | 1.60 | - | - |
| I` | 1.30 | 1.60 | 1.20 | - |
| 1 | 5.70 | 1.70 | 15.90 | 78 |
| 2 | 2.60 | 2.30 | 18.20 | 78 |
| 3 | 2.70 | 1.90 | 18.20 | 78 |
| 4 | 4.00 | 1.90-4.50 | 30.0 | 60 |
| 5 | 2.20 | 1.30 | 36 | 60 |
| 6 | 4.90 | 1.80 | 36 | 60 |
| 7 | 3.80 | 4.0-4.50 | 75 | 40 |
| 8 | 3.10 | 1.90 | 65 | - |
| 9 | 3.10 | 2.20 | 62 | - |
| **II** | 5.60 | 1.40 | 15.00 | - |
| 10 | 3.30 | 2.50 | 35 | 62 |
| 11 | 3.20 | 2.80 | 33 | 62 |
| 12 | 2.30 | 0.50 | 15 | - |
| 13 | 3.30 | 1.90 | 15 | - |

*Fragments 1-7 and I' were measured from cliff "I", 10-11 – from cliff "II".

## 5. Discussion and conclusions

Owing to field observation, processing of measurement data and compiling the scheme of paleoseismodislocation we have the following results:

1. *Size of paleoearthquake.* Overturned limestone blocks are scattered across the slope far from the base cliff (over 70 m). This is a real proof of strong seismic ground motion, and according to the Solonenko's classification of seismic evidence this type of structure formed after the $W_L$>4.5 earthquake (more than 6 points on the MSK-64 scale).
2. *Paleoearthquake's location*. Azimuth direction of horizontal displacement of most of the blocks in the Komariv is 75° (northeast). We compared it with the approximate direction of seismic wave from Vrancea, local rifts, and Berda-Narol fault. This analyse resulted that studied paleoseismodislocations were formed by local earthquake (regional faults in conjunction zone between the East-European platform and Carpathian Foredeep), because Vrancea zone has more northerly location.
3. *Paleoearthquake dating.* According to archaeological evidence this seismic event could take place in between 1.000 BC and XVI-XVII centuries. Maximum age obtained on material dating from before a paleoearthquake. The cliff has mythical creatures and close to the cliff we observed a block with carved in sacrificial-bowl belong to Early Iron Age. The Minimum age are obtained from traces of artificial cutting on block №7. So studied seismodislocations are of Holocene age.

Holocene seismodislocations in Kelmentsy district of the Dniester area are the evidence of strong seismic activity on this area in the past. The results of seismodislocation's measurements, mechanism and causes of their formation should be considered in seismicity of the territory to use that information to increase public awareness of seismic hazards or mitigate the effects of future earthquakes.

## References

Artukh V., Ridush B., Stankevych V. 1997. Megalithic cult complex on the Dniester River. *Pytannja istorii, istoriografii, dzhereloznavstva ta arhivoznavstva Tsentralnoi ta Skhidnoi Evropy I,* Chernivtsi, 225-230. (In Ukrainian)

Vakhrushev I.B. 2001. Seismogeomorphology of Mountain Crimea: the processes and factors of seismomorfogenezis, Cultura *Narodov Prichornomorya* **26***,* Simferopol, 51-54. (In Russian)

McCalpin J. P. 2009. *Paleoseismology* (2nd Edition*),* Academic Press.

Koroljuk I.K. 1952. Podilsky Tovtry and conditions of their formation. *Trudy Instituta Geologicheskikh Nauk, Geologicheskaya serija* **110***,* Moscow, 1-140. (In Russian)

Gerenchuk K.I. 1978. *Nature of Chernivtsi region,* Chernivtsi, 1-160. (In Ukrainian)

Ridush B. 2008. Bakota-Komariv bilateral rock-cave complex, *Archaeologichni Studii* **3***,* Chernivtsi, 223-232. (In Ukrainian)

Sagalova E. 1969. Two questions on seismic zoning of the Bukovina territory. *Seismichnost Ukrainy,* Kyiv, 70-76. (In Russian)

Solonenko V. 1970. The scars on the face of the Earth*. Priroda* **9**, Moscow, 17-25. (In Russian)

Solonenko V. 1973. Paleoseismogeology, *Fizika Zemli* **4,** Moscow, 3-13. (In Russian)

Thegelnuk P. 1974. Silurian Dniester reference section, *Stratigrafia SSSR* **4***,* Moscow, 63-110. (In Russian)

Vakhrushev I.B. 2001. Seismogeomorphology of Mountain Crimea: the processes and factors of seismomorfogenezis. Cultura *Narodov Prichornomorya* **26***,* Simferopol, 51-54 (in Russian).