

THE RED LAKE LANDSLIDE (UCIGAȘU MOUNTAIN, ROMANIA)

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Abstract: The Red Lake is one of the few great natural lakes formed by a landslide in Romania with a surface of 30 ha. Today, specialists have two theories about the triggering mechanism. The first one accepts that the landslide was triggered in 1837 during a heavy rainfall period. The second one refers to the earthquake from January 11 (January 23 in new calendar) 1838, which had a magnitude on Gutenberg – Richter scale of 6.7 or even 7.5. During the field work we found another active landslide, situated on the old landslide, but smaller than the older one (3 ha). The materials involved are ranging from silt to boulders and the relief is chaotic. The mapping is difficult to achieve because of the thick forest, generally composed by coniferous like *Picea abies* and *Abies alba*. The motion of the new landslide was of a few meters and relatively smooth. This fact is proven by the tilted trees, which have a large parabolic trunk without visible scars. By means of dendrogeomorphology we tried dating the new landslide. The method involves extraction of increment cores from the tilted trees located on the landslide, but also of cores from undisturbed trees located near the site, necessary to build the reference chronology. For extracting the cores, an increment borer with 40 cm length and 6 mm diameter provided by Suunto was used. The increment borer was introduced into the trunk and an extractor provides a core of 5 mm in diameter. The landslide samples for dating were collected out of 20 tilted trees, 15 of them located in the front or lateral lobe of landslide. The results relieve that at least two major movements of the new landslide occurred in 1953 and 1979.

Key-words: Red Lake, landslide, natural dam, dendrogeomorphology, tilted trees.

1. INTRODUCTION

Landslides are a type of mass movements, which affects slopes from mountain and hilly regions (Cruden & Varnes, 1996). Depending of the magnitude, it may produce material, financial and life losses. Some landslides can create special sites and landscapes. Such a case is the Red Lake from Carpathian Mountains that was generated by a landslide, which occurred in the 19th century, upstream of Bicaz Gorges.

In Romania, the landslides started to be studied many decades ago by geologists, engineers-geologists, geomorphologists and engineers-agronomists. The investigation methods differ a lot. Hereby, the geologists and engineers-geologists took into consideration punctual analysis (one or few landslides), while the geomorphologists studied morphology, spatial and temporal analysis on large areas with many landslide (Mihăilescu, 1939;

Dragoș, 1957; Bălțeanu, 1983; Bălțeanu et al., 2010; Surdeanu, 1998; Armaș et al., 2004). The most studied areas from Romania were the Subcarpathian regions and secondly the flysch sector from Eastern Carpathians and Moldavian Plateau.

2. STUDY AREA

The Red Lake landslide is located at the bottom of the Ucigașu Mountain, which is part of the Hășmaș Massif from the Eastern Carpathians (Fig. 1). The landslide begins from the bottom of the cliff, which is 150-200 m high, and continues to the Bicaz riverbed.

The landslide was triggered in the 19th century and created a natural lake – Red Lake, with a surface of 12 ha. In present, there are two theories about the mechanism of triggering.

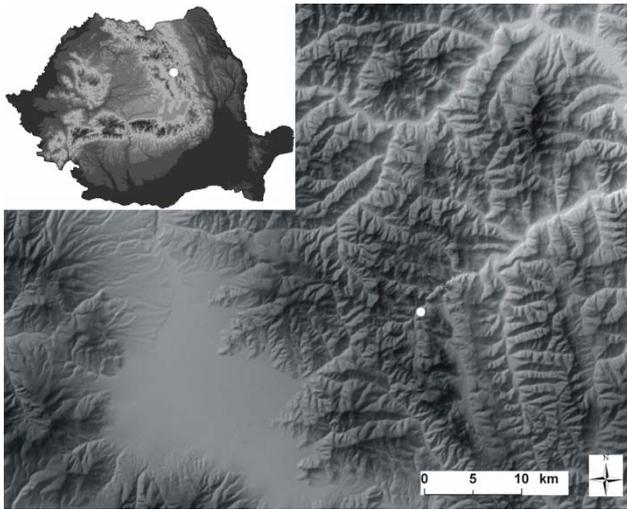


Figure 1. Site location (white dot represent Red Lake landslide).

The first one accepts that landslide was triggered in 1837, during a period of heavy rainfall (Mihăilescu, 1940; Bojoi, 1968 and others). The second one refers to the earthquake from January 11 (January 23 in the new calendar), 1838 (Schueller, 1838), which had a magnitude of 6.7 (Radu, 1979) or even 7.5 (National Institute of Earth Physics seismic catalogue) on the Gutenberg – Richter scale. Herbich (1878) mentioned a heavy rainfall in 1838 as the cause of the landslide. Therefore, nobody knows the exact period of landslide occurrence and the factor that generated it.

The Red Lake landslide was cited and analyzed in many publications since the 19th century (Schueller, 1838; Herbich, 1878; Mihăilescu, 1940; Pișota and Năstase, 1957; Dragoș, 1957; Preda, 1967) and mapped on the geological maps sheets (Atanasiu, 1958; Preda, 1967; Grasu, 1971; Săndulescu, 1975; Săndulescu et al., 1975).

2.1. Geological settings

From the geological point of view, the area is included in the Crystalline Mesozoic Zone (Median Dacides, according to Săndulescu, 1984), on the western part of the Marginal Syncline from the Bucovinic Nappe (Uhlig, 1903; Băncilă, 1958; Săndulescu, 1975). The rocks involved consist of a stratigraphic succession with age from Triassic to Upper Jurassic (Fig. 2).

The most rock here consist of sandstone, grey silt (Middle Jurassic), radiolarite (Oxfordian - Callovian) and limestone, sandy limestone, marl and sandstone (Kimmeridgian).

Generally, the maps show approximately the same stratigraphic succession, interpreted in different ways by different authors. While Săndulescu (1975) and Săndulescu et al. (1975) identified a nappe, others (Preda, 1967; Grasu, 1971) believed that the formations were in normal succession thus they excluded the possibility of a nappe.

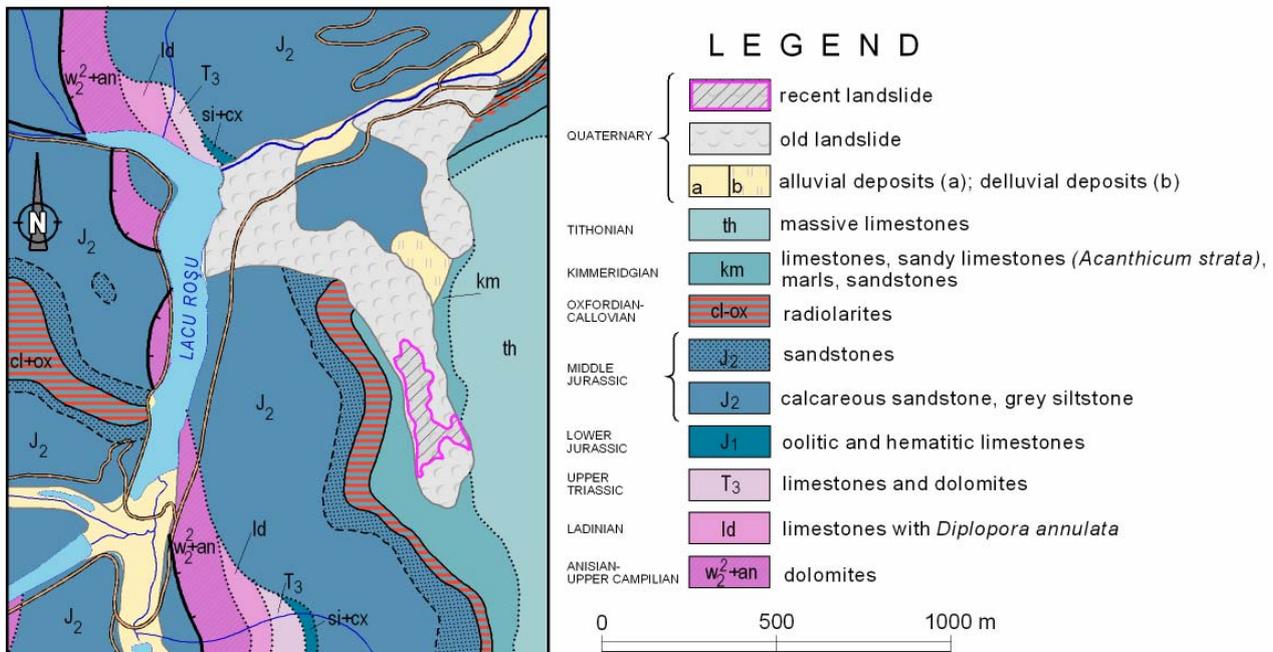


Figure 2. Geologic sketch of the Red Lake area (Săndulescu et al., 1975, modified).

The oldest formations contain dolomites and were dated to Anisian – Upper Campilian (Fig. 3). On this deposit, there are Middle Jurassic deposits, which consist of calcareous sandstone, grey silt and sandstone and occupy a much larger area near the Red Lake. Callovian - a thick, but obvious layer of radiolarite (jasper) which was identified in the field by all authors represents Oxfordian here. The Kimmeridgian is made up of limestone, marl and sandstone. The uppermost formation is represented by Tithonian, is located on the top of the Ucigaşu Mountain and consists of massive limestone, which dips 30-40° to the East.

2.2. Geomorphologic settings

The relief is influenced by the large extension of the Mesozoic deposits, which consist here of limestone and conglomerate. Ucigaşu Mountain is a rocky mountain with a lot of debris at the bottom of its steep walls.

The Red Lake landslide differs greatly from the other landslides in Romania with respect to its lithologic background. It seems that regolith was formed due to red limestone, marls and green sandstones (Kimmeridgian age) alteration which generated clayey material (Preda, 1967). On the surface of regolith, there are many boulders, some of them with more than 5 m in diameter, which resulted from the disaggregation of the rocks from the steep wall of Ucigaşu Mountain. A part of the rocky debris is possible to have resulted during the Pleistocene glaciations, when the entire area was modeled in periglacial climate. Other rocky debris was formed during the Holocene (postglacial period) and the disaggregation process continues in the present.

NW

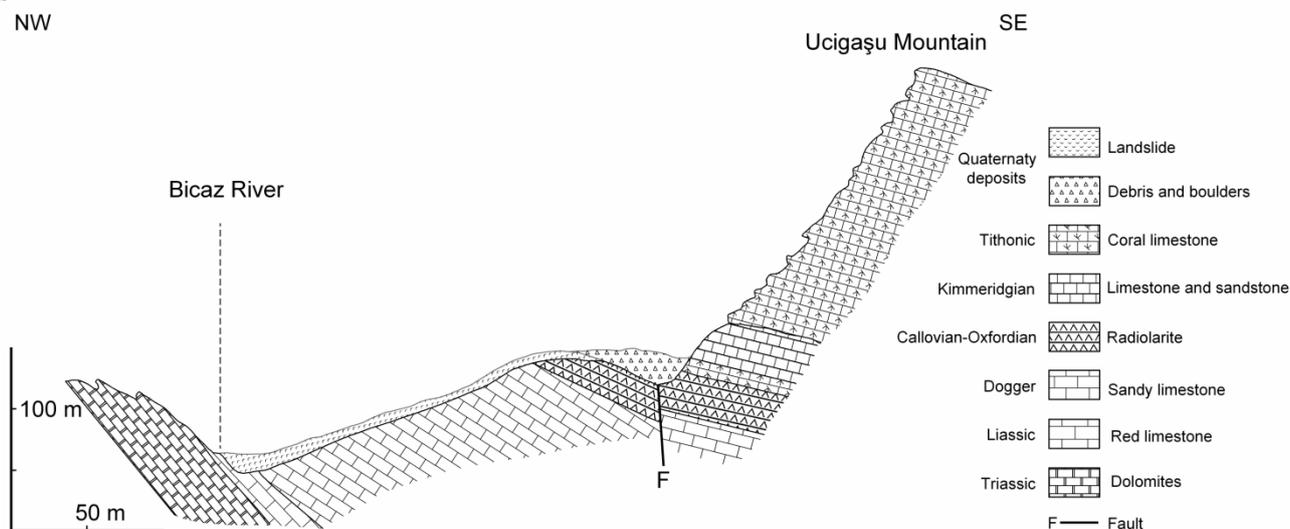


Figure 3. Cross-section between Ucigaşu Mountain and Red Lake (Preda, 1967).

Mihăilescu (1940) pointed out three steps in the formation of the Red Lake landslide:

- (i) Debris and boulders accumulation, which created a talus slope;
- (ii) Chemical alteration of the bottom of deposit and formation of the clayey material;
- (iii) Landslide triggered after a rainy period due to the moistening.

During the fieldwork, the landslide was mapped at 1:5000 scales. The mapping process was difficult because of the chaotic microrelief and forest density. Wavy landforms, small scars and depressions outlined a landslide body. The final cartographic image accentuated very clearly the shape and the dimension of the old landslide, but also revealed another, smaller, landslide, on the body of the old one (Table 1). The new landslide is generally visible due to the 2-3 m high dislevelment and also because of a frontal lobe. Here, most of the trees are tilted downslope, which indicates a former landslide (Fig. 4a, 4b and 5), but other trees are tilted upslope, a combination referred to in the Romanian articles as "drunken forest" because of the disposition of the trees in all directions. The presence of up-tilt and down-tilt trees creates the impression that the landslide or part of it is a rotational slide.

The Red Lake landslide has SE – NW orientation and has a total length of about 1220 m and 120-190 m width (Fig. 6 and 7). The average slope degree is 15°. The old landslide has a surface of about 22 ha while the new one has only approximately 3 ha. In the bottom part, the landslide toe is spread in lateral on the former flood plain and reaches almost 475 m width. In plan, the landslide has a tongue shape which arched very slowly to NW.

Table 1. The Red Lake landslide morphometry.

Parameters	Old landslide	New landslide
Years of occurrence	1837/1838	1952/1953
Type	deep	shallow
Surface (ha)	22.5	2.96
Length (m)	1220	375
Max. width (m)	190	85
Hmax (m)	1280	1210
Hmin (m)	975	1125
Slope mean (°)	15	15



a



b

Figure 4. Aspects from new landslide: front lobe of landslide (a); secondary lobe from the upper part of the landslide (b). Note the tilted trees consequent with landslide direction.

3. DATING THE NEW LANDSLIDE

We know almost exactly the year of the old landslide occurrence, but we did not have any information about the new landslide. By means of dendrogeomorphology we tried to date the new

landslide. The method is based on the extraction of the increment cores from the tilted trees located on the landslide, but also cores from undisturbed trees located near the site, necessary to build the reference chronology (Alestalo, 1971; Shroder, 1980; Stoffel, 2005; Stoffel & Bollschweiler, 2008; Bollschweiler, 2007).

The samples for landslide dating were collected from a number of 20 tilted trees, 15 of them located on the front lobe or on the lateral lobe (Fig. 8 and 9). Other 3 samples were taken from the middle part of the landslide body and 2 samples near the scarp. From each tree were extracted two cores, one in upslope-downslope direction and one from reverse. The reference chronology was made using 10 samples collected from 5 trees located downslope the landslide lobe which have undisturbed and straight trunks, with no eccentric growth.

An increment borer with a length of 40 cm and a diameter of 6 mm manufactured by Suunto Company was used to extract the cores. The increment borer was introduced into the trunk and with an extractor could provide a core with 5 mm in diameter (Fig. 5).



Figure 5. An example of sampled tilted tree.

Samples were then put into polycarbonate tubes, labeled and let to dry in natural conditions. Then, the increment cores were stuck on wooden mounts and polished with fine abrasive paper. The dust created by the small particles of wood was removed with a vacuum cleaner and then washed

with water to eliminate all particles from the wood surface and to increase the contrast between growth rings. In the next step samples were scanned and stocked as digital images with high resolution. Tree rings were measured with CAROTA software, developed by the Experimental Station of Norway Spruce Cultivation, Câmpulung Moldovenesc (Popa, 1999). The resulted txt format files were used to build the chronology and to date the growth disturbances.

The samples were also examined under microscope to identify the traumatic resin ducts or

TRD (Gärtner & Heinrich, 2009). A special attention was paid to reaction wood (Gärtner, 2007; Butler & Sawyer, 2008; Heinrich & Gärtner, 2008).

4.RESULTS

The analysis of increment cores takes into consideration only the inclination of stem and buried stem. No injury, decapitation or roots exposure were observed during the field work. The main characteristics of the samples are listed in Table 2.

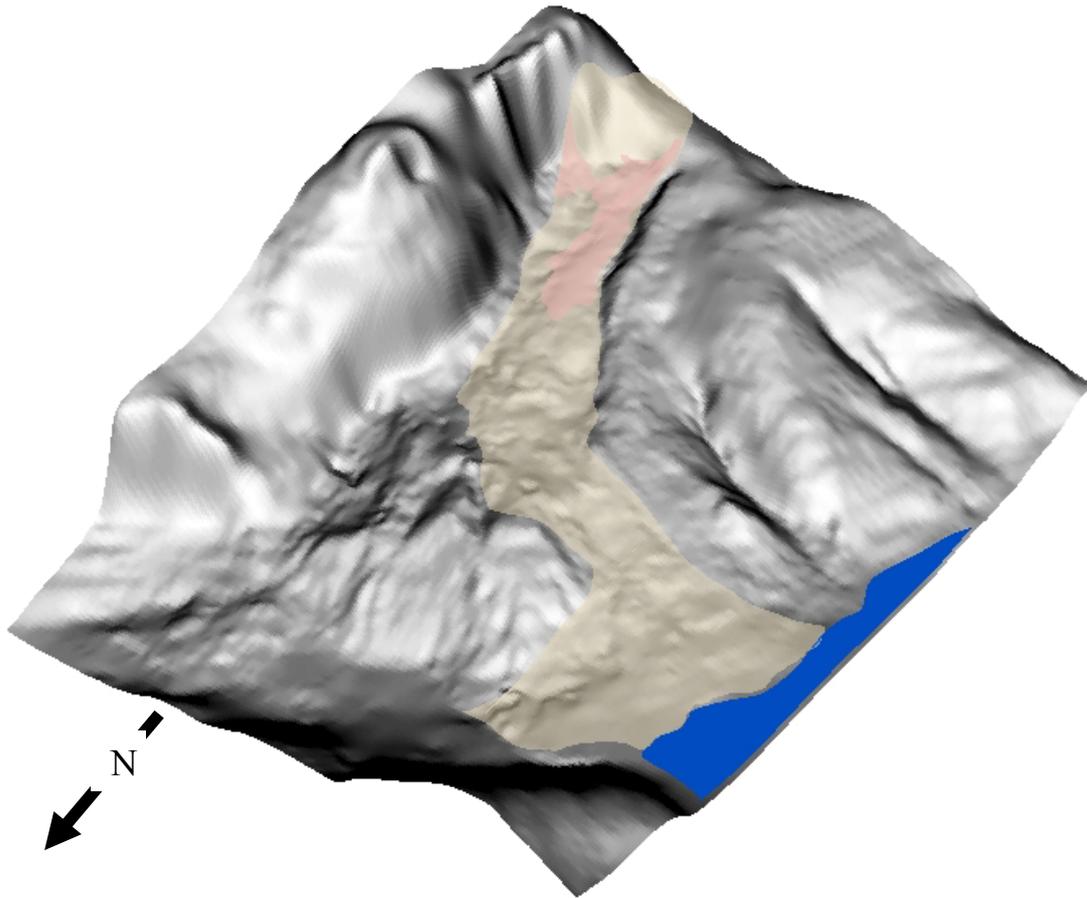


Figure 6. 3D image of the Red Lake landslide. In faded yellow – the old landslide and in faded red the new landslide.

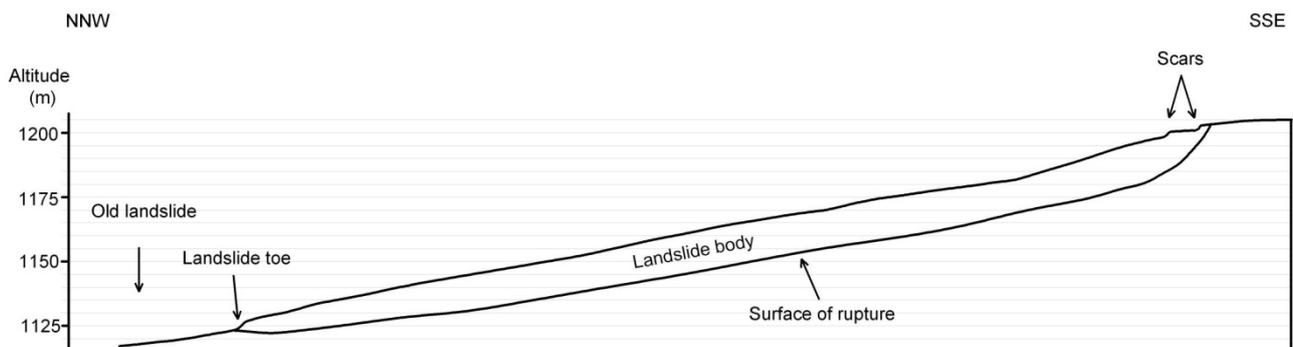


Figure 9. Longitudinal profile of the new Red Lake landslide



Figure 7. Picture taken from Suhardu Mare Peak, with the landslide marked by red line (photo Dan Grigore).

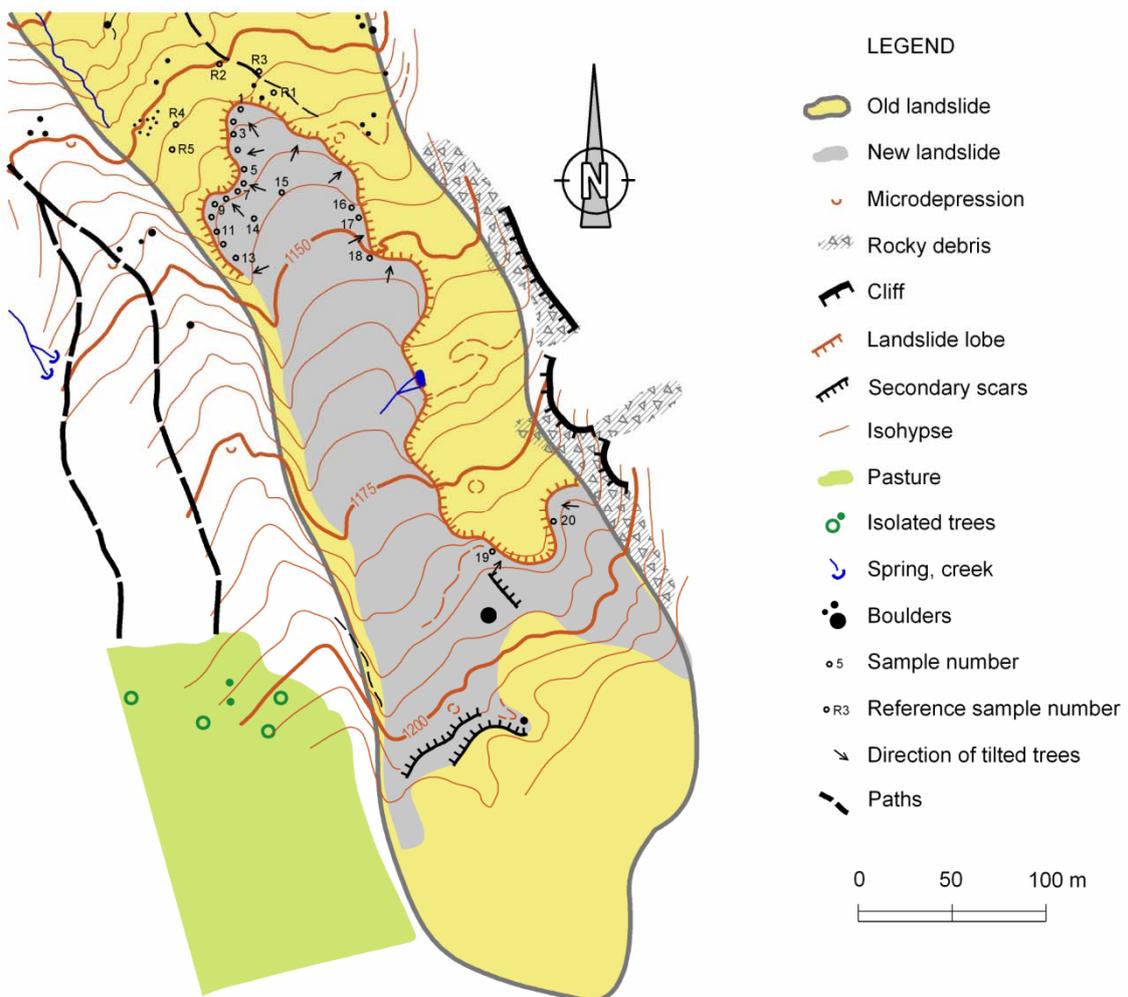


Figure 8. Sketch of the new landslide and location of sampled trees.

Table 2. Sampled trees characteristics.

Tree number	Diameter (cm)	Tilted direction (azimuth)	Dating period (years)	Growth type	Year or period of negative abrupt growth	Presence of the compression wood (interval period)
1	18.5	20	1935	eccentric	1952-1953, 2000	1954-2010
2	34.5	20	1877	eccentric	1953	1917-1922, 1945-2010
3	22.5	330	1929	eccentric	1953	1954-2010
4	17	360	1944	eccentric	1957, 1989	1953-1959, 1971-1979, 1990-1998
5	32	305		eccentric		1953-2010
6	14.5	300	1964	eccentric	1978-1979	1956-2010
7	18	330	1946	eccentric	1985	1954-1962, 1972-1973
8	23	335	1952	eccentric	1959?	1953-2010
9	26.5	350		eccentric		1953-1984, 1993-2010
10	20	285	1958	eccentric		1953-2010
11	17	285		eccentric		-
12	37.5	280		eccentric		-
13	18	260	1942	eccentric	1963	1954-1959, 1972-2010
14	25.5	340		eccentric		1954-1959, 1966-2010
15	30.5	335	1927	eccentric	1957	
16	22	90		eccentric		1955-2002
17	28	25	1936	eccentric	1952-1953, 1985-1986	1953-2010
18	22	55	1977	eccentric	1979	already tilted in 1972
19	26	275		eccentric		-
20	24.5	350	1945	eccentric		-
R ₁	33.5	-	1950	-	-	-
R ₂	31	-	1913	-	-	-
R ₃	34	-	1912	-	-	-
R ₄	35	-	1940	-	-	-
R ₅	27.5	-	1950	-	-	-

Note that R is referring to reference chronology sample.

In dating process we were obstructed by a few problems because we did not deal with a violent landslide but with a slow one. The landslide was moving slowly, which made a correct dating almost impossible; therefore, we could only indicate the possible occurrence interval. Injuries or TRD are missing or difficult to find and dating of starting process is difficult, based only on abrupt growth and presence of the reaction wood.

Despite all difficulties, we found in a few samples evidence of abrupt growth, which indicated a starting process during the years 1952-1953 (samples 1, 2, 3 and 17), 1957 (samples 4 and 15), 1959 (sample number 8 was already tilted which means that trees started to tilt in the first years of life, and also sample number 14), 1963 (sample number 13) (Fig. 10a, 10b and 10c). We have the certitude that the new landslide occurred in the 1950s or it was characterized by high rate of movement in this interval. The gap between the first appearance of the abrupt growth and the second one is perhaps due to the different velocity propagation of the landslide body.

Other samples (two of them) presented narrow rings between 1870 and 1893. It is possible to be the beginning of the movement, but because our reference chronology does not go back before 1915, we cannot tell precisely the causes of this fact. It is unlikely though that the narrow tree rings are a consequence of climatic factor response rather than due to trees competition. Further investigation must identify the oldest trees from the landslide and near it and sample them to enlarge the chronology and reference chronology.

Another abrupt growth was identified for the year 1979 in three samples (samples 6 and 18) collected from the toe and lateral toe of the landslide (Fig. 11). The abrupt growth from this interval was induced probably by another important movement of the landslide. This assumption is partially based on the presence of the two secondary scars from the upper part of the landslide, which indicate a minimum of two important periods of movement. Also, the period between 1985 and 1989 presented a negative abrupt growth.

Based on the recent studies (Stoffel and Bollschweiler, 2009) we can assume that the new landslide occurred between 1953 and 1959 and was followed by another significant slide in 1978-1979. Between these two events and also after the second one, we identified many abrupt growths in the tree ring series, which makes us suggest that the body of landslide pushed almost continuously into the upslope face of the tree trunks. From this reason dating the process was difficult because many samples presented eccentric growth during their entire life period. This means that trees started to growth in the period of movement.

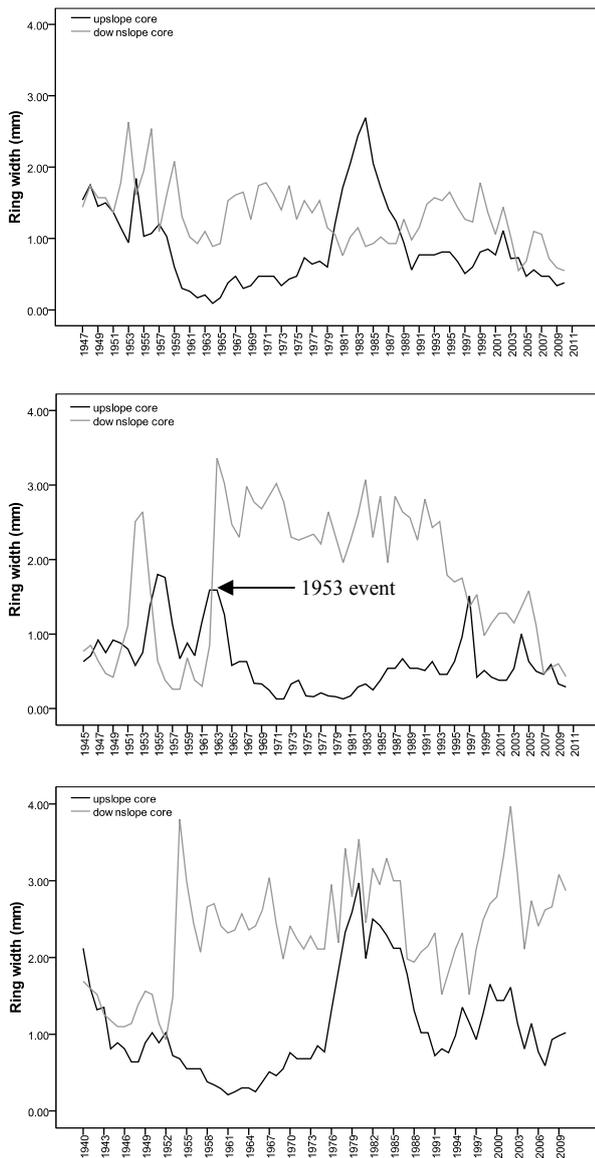


Figure 10. Abrupt growth in a few trees sampled from the new landslide; an event from which started in 1953 was found in trees no. 4, 13 and 17.

The presence of the compression wood in all 20 trees shows that the body of the new landslide is

active and, in consequence, pushes tree trunks continuously. According to compression wood we can roughly tell that the landslide mass action on the tree trunks differentiated a fact which is obvious from the disposition of the reaction wood. In trees from the landslide toe there is compression wood chiefly in the cores while other samples, from the lateral landslide body, have few repeated tree rings with compression wood, which possible can indicate intermittent sliding processes. TRD are missing probable due to the slow sliding which created only a visible anatomic response (eccentric growth).

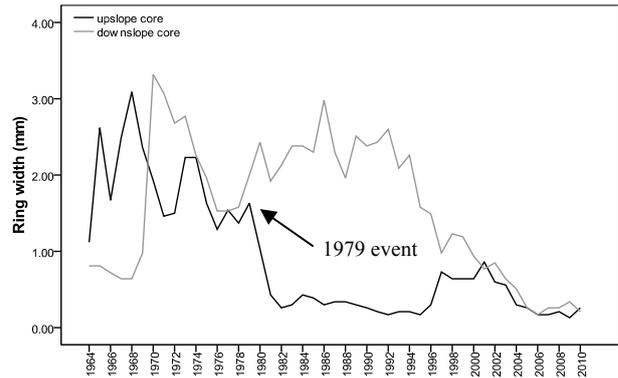


Figure 11. The second event from 1979 dating on tree number 6.

The reaction wood (compression wood) was present in all samples. More than half of the samples started to develop compression wood since 1953-1954 (Fig. 12), which can be correlated with abrupt negative growth in tree 4, 13 and 17. The most relevant samples are presented in figure 12.

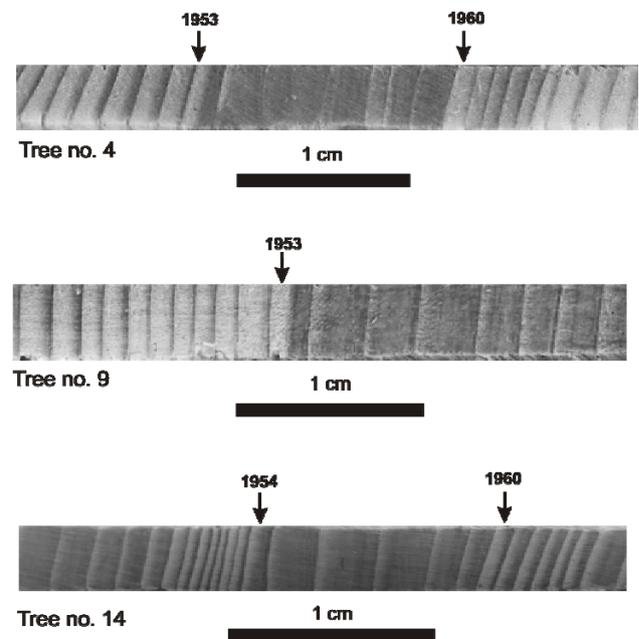


Figure 12. Compression wood located on the downslope part of the trees trunk (sample no. 4, 9 and 14).

Other period of movement, seem to be at the beginning of the '70, between 1971 and 1972.

5. CONCLUSIONS

The Red Lake landslide remains one of the few landslides from Romania which created a beautiful natural heritage – the Red Lake. Further geophysical investigation is needed to detect the depth of the sliding mass. A mineralogical study of the clayey material is necessary to identify the composition and also a geotechnical research must be done to evaluate the slope stability. These studies are important because many constructions (hotels, pensions, chalets and even the national road) were built on the toe of the landslide. Therefore, if a new landslide occurs in the future, the damages will be important and the tourists and local inhabitants could be endangered.

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