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FIRST RADIOCARBON DATING OF LANDSLIDES ("GLIMEE") IN ROMANIA

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Abstract. The deep-seated landslides (glimee) have played an important role in the evolution of the landscape in Transylvania. In Romania the study of the landslides were focused principally on the morphology, the spatial distribution and the influence of human activities on the morphology and on the origin of landslides. Through the radiocarbon dating of the basal layer, the first radiocarbon age (1820 ± 30 years BP) of the landslides from Romania was established. The pollen analysis of this layer confirm the Subatlantic age for the origin of the landslide from Pădurenii (Transylvanian Depression). During this period the vegetation of the studied area was composed by open forest dominated by *Fagus sylvatica*. The results could identify possible period with deforestations which contributed to the landslide occurrence. A multiplication of the landslide age determination by radiocarbon dating coupled with palynological analysis could led to a better understanding of the geomorphological and climate context in which the deep-seated landslides (glimee) occurred in Romania.

Keywords: landslides, radiocarbon data, pollen analysis, Holocene, Transylvania, Romania.

1. INTRODUCTION

The term "glimee" refers to massive landslide processes (and the resulting landforms) which affect both the superficial deposits and the geological substrate (tens of meters) (Gârbacea, 2013). The deep-seated landslides (glimee) have played an important role in the evolution of the landscape, in Romania in general and particularly in Transylvania (Gârbacea, 1992).

In Romania, the previous studies of the deep-seated landslides were focused principally on their spatial distribution (Gârbacea, 1964, 1992; Morariu & Gârbacea, 1968; Surdeanu et al., 2011) and morphological changes caused by human activities (Moldovan & Pandia, 2012). The surfaces covered with glimee are variable in extension and form, from simple mounds or ridges to large areas with (6 to 15 km^2) where complex morphology can be distinguished. The later includes hundreds of positive microforms, occasionally as chains, and tabular landforms, transversal and longitudinal depressions with micro-depressions, sometime occupied by wetlands or lakes, or even drained (Gârbacea, 1996).

This is the first study that addresses the problem of determining the age of the landslides (glimee) in Romania through the radiocarbon dating.

2. STUDIED AREA

The landslides of Pădurenii (47º04'52" N, 23º59'21" E, 420 m altitude) are located in the high hills called Unguraş Hills, in the north-western part of the Transylvanian Depression, north-east of the Gherla city (Fig. 1).

Geologically, the area consists of Badenian marly clays and sandstones in the base. Above it, there is a package of impermeable clay or marl, which also include Sarmatian volcanic tuffs. The thalweg of the Dosului Valley is carved in Badenian sediments, while the upper slopes and the top of the hills are composed of Sarmatian rocks, more friable and permeable: sandstones, sands with concretions, and horizons of variable thickness of volcanic tuffs (Dumitrescu, 1951).

Geological deposits of the studied area have a slight slant to the west; this area overlaps the eastern

flank of a syncline whose axis is drawn by the Dosului Valley, between Fizeşu Gherlii and Nireş, on south-north direction. As a result, the landslides of Pădurenii are consequents.

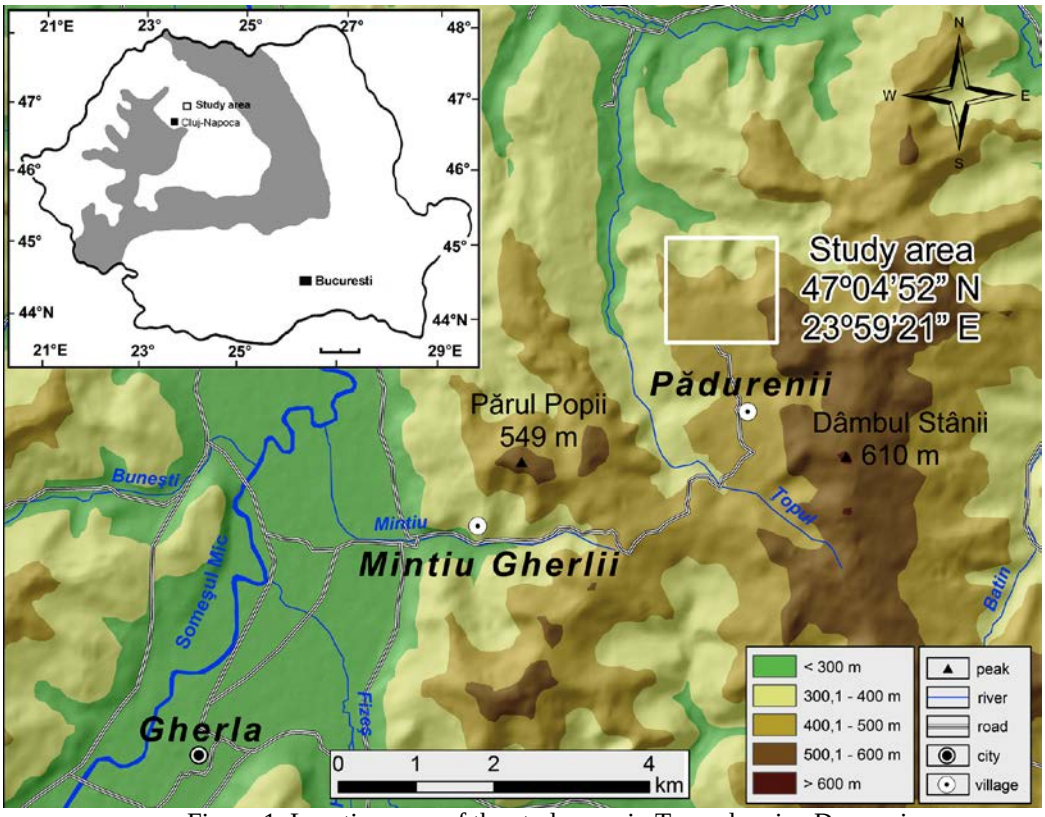

Figure 1. Location map of the study area in Transylvanian Depression

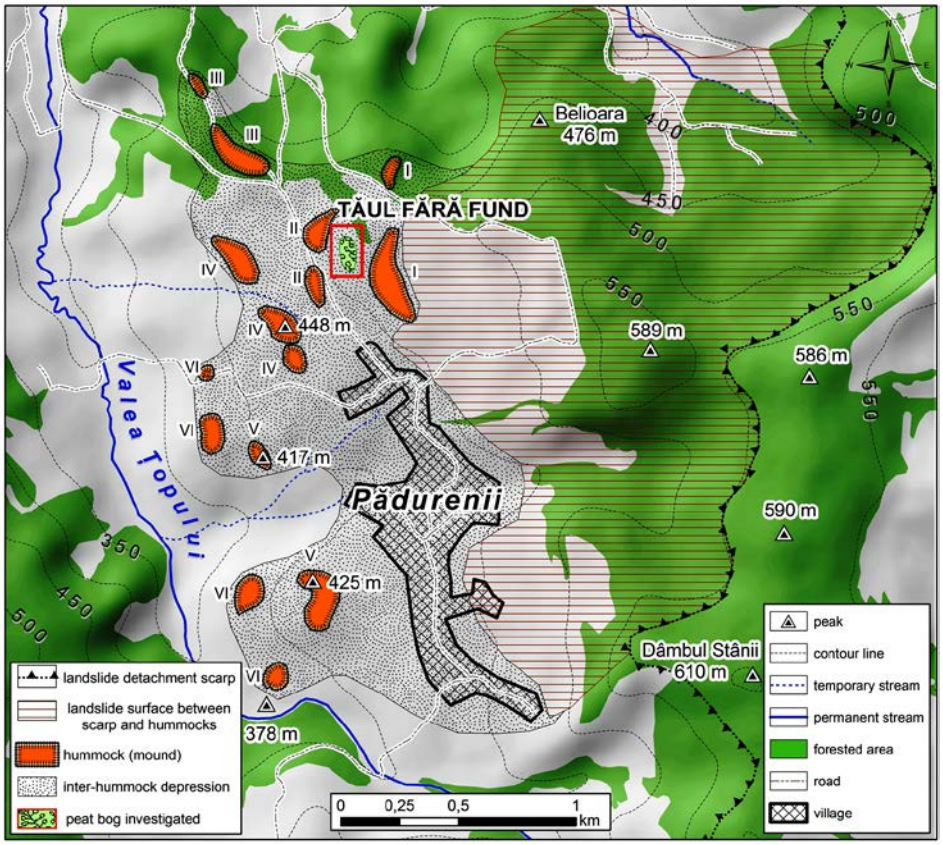

Figure 2. Geomorphological sketch map of the Padurenii landslide and location within the study area of Tăul Fără Fund peat bog investigated

During the sliding, the sediment strata were fragmented and it has formed 5-6 alignments of secondary peaks and mounds. In a longitudinal depression between the first two rows of these landslides, a peat bog named "Tăul Fără Fund" was formed (Fig. 2). The peat bog has an oval shape, a thickness of ca. 300 cm and occupies an area around 1ha.

The vegetation surrounding the peat bog is mainly composed of diverse species of *Salix*. The peat is covered with *Betula verrucosa, Alnus glutinosa, Populus tremula, Carex vesicaria, C. rostrata, Scirpus silvaticus, Eriophorum angustifolium, E. latifolium, Parnasia palustris* (Diaconeasa, 1985).

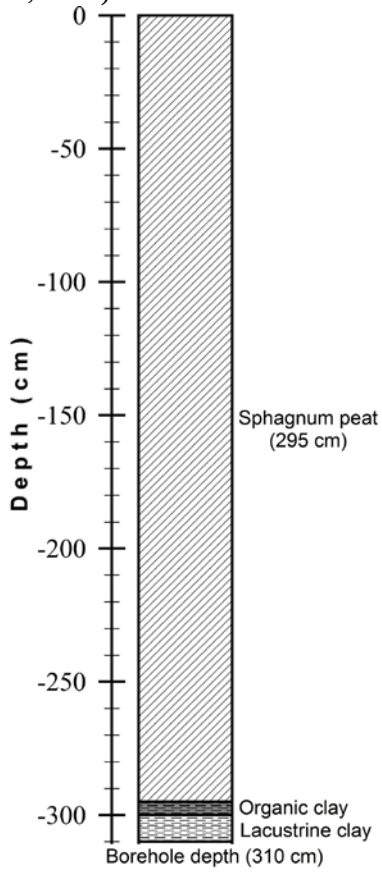

Figure 3. Litostratigraphic column of Tăul Fără Fund peat bog

3. MATERIALS AND METHODS

The radiocarbon age was obtained at Beta Analytic Radiocarbon Dating Laboratory from Miami (Florida). A sample taken from the bottom part of the sequence (295 cm depth), from the sliding surface, at the limit between the peat and the basal clay was used (Fig. 3).

Another sample, from the same level was used for the pollen analysis. The frequencies of pollen for each taxon were calculated as percentages of the total sum (AP+NAP). For ecological reasons the spores and the cyperaceous pollen were excluded from the pollen sum.

The mineralogical composition of the basal clay was determined using X-ray diffraction.

4. RESULTS

4.1. Lithology and mineralogy

The entire sequence is 310 cm in length. The lowest part (10 cm) consists on lacustrine clay, over which is 5 cm of organic clay (300-295 cm depth). Most of the sequence (295-0 cm) is represented by a *Sphagnum* peat (Fig. 3).

Mineralogical composition of the analyzed sample corresponds to clay in which the phyllosilicates are represented by illite, muscovite, and kaolinite. Other minerals presents are quartz, plagioclase feldspar (albit-anorthite) and subordinate carbonates (dolomite/calcite). The dark color of the sample in the wet state is due to the high content of organic matter.

4.2. Radiocarbon age

The radiocarbon age obtained for the landslides from Pădurenii is at least 1820 ± 30 year BP (1694-1825 cal yr BP). This value places the age of the landslide in the Subatlantic period.

4.3. Pollen analysis

For better the understanding of the vegetation composition and the palaeoenvironment around the site during the landslides period, a palynological study was performed (Table 1). One sample was analyzed at the limit between the peat and the basal clay. The pollen analyses show for this period that the vegetation around the site was composed 46% (59%) by trees and 37% (41%) by herbaceous plants. The vegetation on the peat bog was represented also ferns (Pterydophyta) and *Sphagnum* (Bryophyta) (Table 1, Figs. 2 and 3).

The forest vegetation were dominated by *Fagus sylvatica* (52%) and *Carpinus betulus* (23%) *Quercus, Alnus, Ulmus* and *Betula* were also present with lower percentages (Table 1, Fig. 4).

The herbaceous are dominated by pollen of Poaceae (> 8%). The pollen of unspecified cereals, *Rumex* and *Plantago lanceolata* is also present with low percentages.

5. DISCUSSIONS AND CONCLUSIONS

The landslides (glimee) are very characteristic for the landscape of Transylvanian Depression. Very

few studies have appeared regarding the relative age of these landslides (Morariu et al., 1964).

The radiocarbon data obtained (1820 ± 30 year BP) for the sample, taken from the sliding surface, at the limit between the peat and the basal clay, place the age of the landslide in the Subatlantic period. The calibrated age is between 1694-1825 cal yr BP (256-125 AD).

The pollen analyses show that for this period the vegetation was represented by open forests dominated by *Fagus sylvatica* and *Carpinus betulus* (Figs. 3 and 4). *Quercus*, *Alnus*, *Ulmus* and *Betula* were also present in the studied zone (Table 1). These results confirm the Subatlantic period for the origin of the landslides. The presence of open deciduous forest in the region was also identified by pollen analyses on lacustrine sediment from Lake Ştiucii, near our site (Feurdean et al., 2013).

In Romania, forests dominated by *Fagus sylvatica* are characteristic for the Subatlantic period (ca. 2600 cal yr BP to present days) and were identified in other zones of the Transylvanian Depression (Tanţău et al., 2006, 2011, Geantă et al., 2012) or in the Romanian Carpathians (Feurdean, 2005; Feurdean et al., 2009; Tanţău et al., 2009, 2014a,b; Fărcaş et al., 2013).

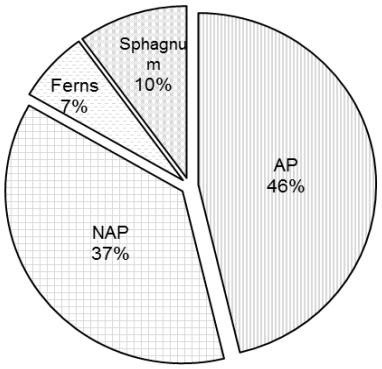

Figure 2. Main components of pollen and spores

Table 1. Composition of vegetation in the studied area: AP = arboreal pollen, NAP = non-arboreal pollen (herbaceous)

AP taxa	**% of AP**	**% of AP+NAP**	**NAP taxa**	**% of AP+NAP**
Pinus	0.9	0.5	Poaceae	8.4
Picea abies	1.8	1.0	Cereals	1.0
Abies alba	0.9	0.5	*Artemisia*	2.1
Fagus sylvatica	51.4	30.2	Scrophulariacea	4.8
Carpinus betulus	23.4	13.7	*Plantago lanceolata*	1.1
Quercus	6.3	3.7	*Rumex* type	0.5
Ulmus	1.8	1.1	Ranunculaceae	2.6
Tilia	0.9	0.5	Rosaceae	1.6
Fraxinus	0.9	0.5	Lamiaceae	1.6
Acer	0.9	0.5	Brassicaceae	1.1
Corylus avellana	1.8	1.1	Urticaceae	1.1
Alnus	4.5	2.6	*Cannabis* type	1.1
Betula	2.7	1.6	Cyperaceae	5.2
Salix	0.9	0.5	*Potamogeton*	1.6
Cornus type	0.9	0.5	Div. herbaceous	12.2
			Spores - ferns	8.4
			Sphagnum	10

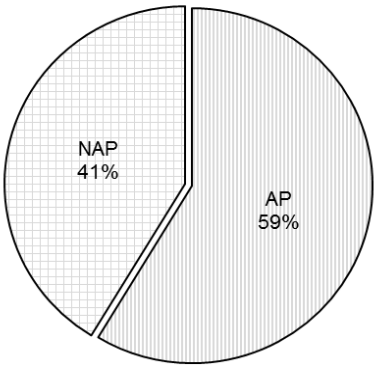

Figure 3. AP/NAP ratio.

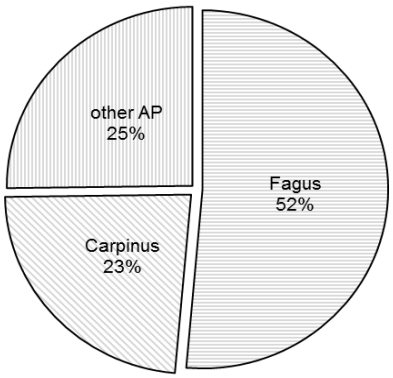

Figure 4. Principal trees components of vegetation (calculated from 100% AP)

The pollen of cereals, *Plantago lanceolata*, *Rumex* and *Cannabis* type suggest anthropogenic activities in the studied zone, namely agriculture and animal husbandry.

The pollen analysis of the entire sequence could be useful for the reconstruction of the vegetation dynamics (especially for trees). The results could identify possible period with deforestations which contributed to the landslide occurrence.

The age obtained in this study is not similar with that concluded by Diaconeasa (1985) and Buz et al., (1986). Based only on palynological data, especially on the higher pollen percentages of *Carpinus betulus*, than those of *Fagus sylvatica*, the authors were establishing the end of the Subboreal period for the beginning of the peat bog formation. The inconsistency between this result and the radiocarbon age obtained in this study and confirmed by pollen analysis could be explained by an overrepresentation of the *Carpinus* pollen in the study of Diaconeasa (1985).

High percentages of *Carpinus* pollen, except those from the Subboreal period, correspond with the return of this tree during the Subatlantic period, when, at lower altitudes, the hornbeam has formed mixed forests with oak and/or beech (Diaconeasa & Fărcaş, 1998. This event was identified in other sequences from Romania (Tanţău et al., 2006, 2011).

The extension of the hornbeam forests in the Transylvanian Depression can be related to the specific environmental conditions of this zone in the present days, and that probably occurred at the end of the Holocene (Subatlantic).

A more complete answer to the problem of deep-seated landslide age in Romania can only be given by multiplying the age measurement, correlated with palynological analysis.

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