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RAINFALL INFLUENCE ON LANDSLIDE DYNAMICS (CARPATHIAN FLYSCH AREA, Romania) (**)

ABSTRACT: SURDEANU V., RUS I., IRIMUS I.A., PETREA D. & COCEAN P., *Rainfall Influence on Landslide Dynamics (Carpathian Flysch Area, Romania)*. (IT ISSN 0391-9838, 2009).

This study brings forward two important aspects concerning landslides that have an important role in the contemporary morphogenesis of the hilly and mountainous areas in Romania.

The first topic refers to the recurrence of the landslides reactivation. The existing works proved that the starting point and the recurrence of landslides are mainly connected with the climatic periodicity, especially with the pluviometric surplus. For the mountainous flysch area, the periods with surplus of precipitation were recorded between 1912-1913, 1941-1943, 1970-1972, 2000-2005. Recent field studies, during the last two periods, show (on the background of a natural vulnerability) an extension of the area affected by active landslides.

The second aspect that was taken into account is connected with the implications of the meteoric water on the landslide dynamics. In order to emphasize this relationship, the analysis was based on the measurements of the rainfall regime, moisture of the slope deposits as well as the landslide dynamics made in two experimental catchments. In order to measure the landslides dynamics, repeated topographical and inclinometric measurements were taken. The research was carried out over two years so as to identify the influence of the precipitation on two types of superficial deposits affected by active landslides.

The investigations helped us reach the conclusion that the daily precipitation influences the moisture of the slope deposits only up to a depth of 50-60 cm. Between the date when the rain occurs and that when the landslides are accelerated, there is a difference of 10-15 days according to the infiltration rate which depends on the grain size of the deposits and their degree of disintegration.

KEY WORDS: Precipitation, Slope deposits, Natural humidity, Landslide dynamics, Eastern Carpathians, Romania.

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INTRODUCTION

Among the factors that determine the genesis and maintenance in a dynamic state of the landslides, most of the researchers point out the role of the precipitation (Tufescu, 1966; Flageollet, 1989; Panizza, 1995). If some of the authors explain the mechanisms through which the landslides take place in the presence of water and under its influence, in most of the cases it is not explained "how" and "when" water interferes in the landslide dynamics. Therefore, our aim, based on field experiments, is to elucidate some of the aspects connected with precipitation and the landslide dynamics.

Our research was carried out beginning with 1970 till present days in the Eastern Carpathians (the flysch area) and was aimed to point out the extension of the active landslides, the triggering factors that led to the reactivation of the previous surfaces affected by landslides over time and their impact on the local economy (fig. 1).

Ranging in longitudinal strips from north to south, with widths that exceed 100km in the southern part, the flysch formation consists of lithological entities with ages beginning with the Cretaceous up to the Neozoic, represented by rhythmical alternations of marls, clays, sandstones, marly- limestones and aggregations (Bancila, 1958).

The Bistrita valley represented the main focus of our research as it crosses, from north-west to south-east, all the morpho-lithological units of the above mentioned mountains, having a roughly transversal direction in its middle part.

Beginning with the 1950s, the Bistrita valley has been highly transformed due to the hydro-energetical constructions that have been developed here. Five reservoirs have been built so far. Under these circumstances, some direct impacts could be identified, such as: village removal, road

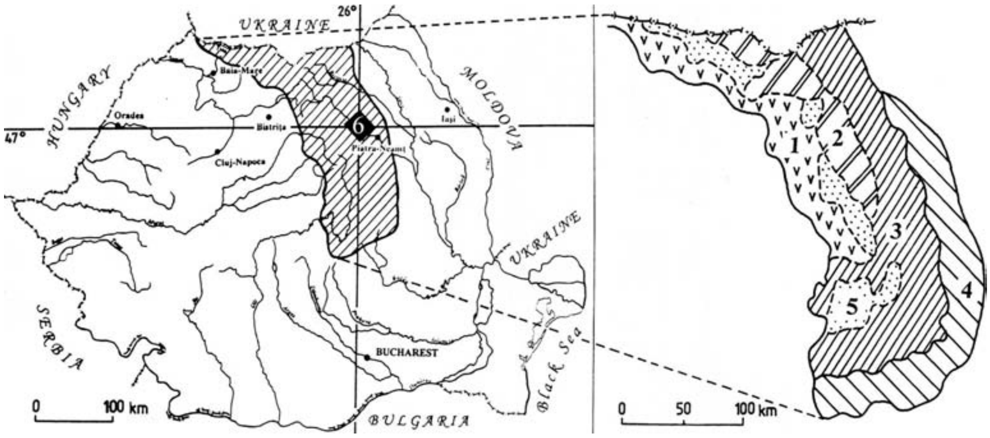


FIG. 1 - Site maps of Romania's territory showing the location of the Eastern Carpathians; 1. Volcanic rocks; 2. Crystalline and Mesozoic sedimentary rocks; 3. Flysch rocks; 4. Neogene molasse; 5. Mountain tectonic depressions; 6-Experimental catchments position in the Bistrita Valley.

construction, land use changes, etc. all affecting the stability of the slopes (Sandru & *alii*, 1960; Donisa, 1968; Ichim, 1979; Surdeanu, 1997, 1998).

Between 1970 and 1990, in the Bistrita valley, in the flysch area, there were more than 500 landslide bodies identified. Most of them exceeded a surface of 1 ha and, all in all, they represented 10% out of the whole surface of the studied area. They caused damage to buildings, to public roads and deteriorated large surfaces of forests and grass land, and together with the quantity of alluvium carried by the rivers they became the main sources of filling material of the reservoirs (Radoane, 2004; Surdeanu, 1998).

MATERIALS AND METHODS

After some preliminary investigations, seven catchments were chosen to be studied. Their surface ranges between 150 and 220 ha. The observations that were carried out (1970-1990) focused on the landslide dynamics in relation to their triggering factors. For exemplification, we chose two catchments, Buba and Huiduman, that are placed in different lithological and morphological conditions.

In each of the two experimental catchments, where the active landslides represent an area ranging from 13% to 40% of the whole surface, a shallow landslide was selected (of more than 10 m thick) and with affected surfaces of over 5 ha; they were subject to topographic, inclinometric, hydro-geological and pluviometric measurements.

The data collected were related to the physical and mechanical properties of the colluvium deposits, to rainfall regime, to vegetation and human impact over time.

In order to quantify the influence of the rainfall on the superficial deposits and the dynamics of the landslides, there were collected samples in drills. Whenever the landslides were measured, we uncovered the surface that was subject to measurements, over a depth of 30-40 cm, so as to eliminate the possible influences on the state of the slope deposit. Thus, the relationship between the soil moisture and the amount of rainfall was measured. These results were correlated with the topographic (made twice a year) and inclinometric measurements (made monthly).

RESULTS AND DISCUSSIONS

The investigated landslides have a surface that exceeds 5 ha. They activate the superficial deposits and the surfaces where postglacial dormant landslides can be found. In both experimental catchments, by taking into consideration the written records, we could identify reactivations over the previous century in three periods.

The superficial deposits in the two investigated catchments are thicker than 35 meters, at the base of the slopes due to the transfer of superficial deposits through landslides. Their characteristics are presented in figure 2 and table 1.

TABLE 1 - Physical characteristics of the superficial deposits in correlation with the primary lithological entities

Lithological deposits	Lithological strata	Grain size > 2 mm	Grain size 2-0.05 mm	Grain size mm 0.05-0.005	Grain size < 0.005 mm	Average diametre (mm)	Skeleton-matrix ratio	Clay fraction from the matrix	Plasticity limits High limit	Plasticity limits Low limit	Plasticity index	Consistency index	Porosity	Unit weight	Colloidal activity
Teleajen	Cotumba	3.6-	25.6-	24-	24.3-	0.0008-	1:3.3-	30.7-	45.5-	16.5-	29-	0.5-	–	–	1.1-
	Lutu Roşu	20.0	27.6	34.3	43.7	0.015	1:20.7	45.8	49	19.1	30	0.9			1.9
Tarcău	Inocerami	12.7-	12.4-	9.9-	14.6-	0.003-	1:0.7-	34.6-	37.4-	15.2-	20.8-	0.8-	40-	1.61	0.6-
	27.1	35.5	30.5	48.2	0.024	1:4.3	58.5	55.2	19.8	36.4	0.9	70		3.5	

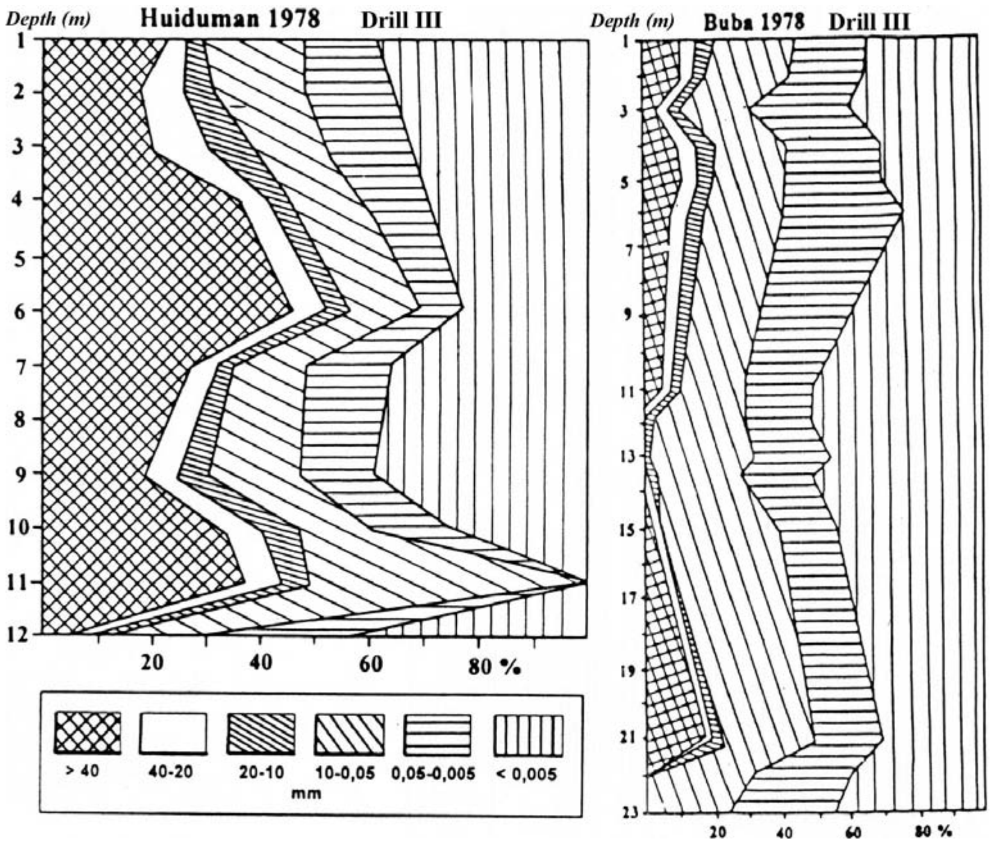


FIG. 2 - Grain size of the superficial deposits.

It can be noticed that in both cases the clay fraction represents 15 to 48% out of the whole samples, and the fine one -the matrix (under 1 mm in diameter) ranges between 60% (Huiduman) and 80% (Buba). In the matrix, there are rock fragments (sandstone, marly limestone) disseminated with diameters that range from centimeters (Buba) to decimeters and meters (Huiduman).

Both landslides evolve in a temperate climate with moderate influences due to the nearby reservoirs. The annual temperatures range around 7-8 ºC and the average annual amount of precipitation is around 550 mm. The layer of snow lasts 60-70 days per year, and the soil is frozen between October and April.

In the rainfall regime, there are huge variations as there were years when the amount exceeded 1000 mm. By analyzing the precipitation (the average amounts on 3 years), in the Bistrita valley the following rainy periods were identified: 1885-1899; 1909-1913; 1936-1942; 1969-1974; 2005-2007. They alternated with dry and very dry periods. Between 1909 and 1913 the surplus of precipitation over the annual average was of 300 mm; between 1936 and 1942, it was 150-200 mm; and between 1969 and 1974, it ranged between 100-150 mm. There could be noticed an obvious decrease in the pluviometric surplus over the 20th century (fig. 3). In these periods with surplus of precipitation, the landslides were reactivated on large areas.

In the literature, there were identified more rainy periods: 1313-1317; 1342; 1370; 1404; 1456-1457; 1490; 1526-1533; 1593; 1618; 1805; 1831-1837 (Topor, 1964).

At the seasonal level, between October and April, the amount of precipitation represented only 9 to 35% out of the annual amount, most of it being represented by snow (60-100 mm at Buba; 20-80 mm at Huiduman). In spring and summer, when the temperature is always above 0ºC, precipitation represented 65-91%, the rainiest period being between April and June. The total number of rainy days varied between 120-140 days, out of which 18-22 days had more than 10 mm (Mihăilescu, 2001).

Between 1977 and 1978, pluviometers were installed in the two experimental catchments and the results were as follows:

- between June 15 and September 30, 1977, there were 62 rainfall events in 59 days, with a total amount of 261.6 mm at Buba. At Huiduman, there were 45 rainfall events in 42 days, with the same amount of rainfall;
- in 1978 (between May 1 and September 30), there were 160 rainfall events recorded in 72 days with an amount of rainfall of 565 mm; for the same period at Huiduman, there were 128 rainfall events in 71 days with 582.3 mm;
- the period when the superficial deposits moisture was very high began in early April and ended in June. This was possible due to the storage in the superficial deposits of the water coming from the snow melting and

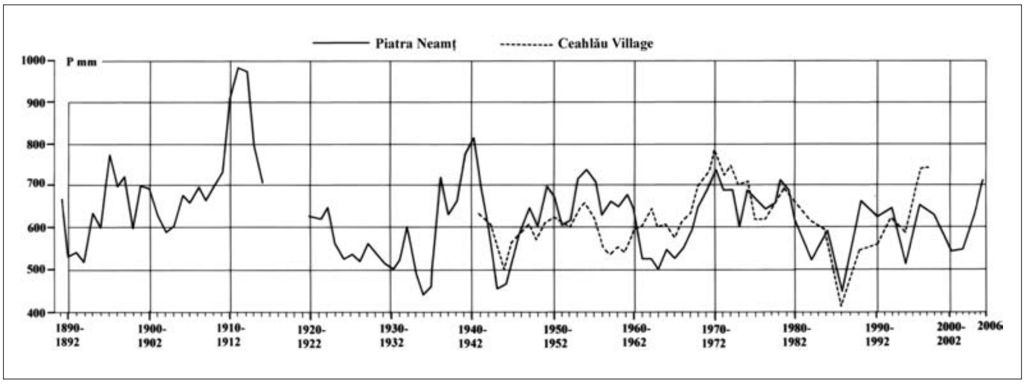


FIG. 3 - Amount of precipitation in the Bistrita Valley (mean values over a three-year period) (after I.N.M.H. Annuary).

from rainfall. The water that comes from snow melting is subject to infiltration together with the rainfall;

- in the Huiduman catchment, the natural moisture varied between 20 and 25% on a profile of 140 cm, and in the case of the Buba catchment it exceeded 35% (fig. 4);
- the rainfall influenced the moisture of the superficial deposits (up to 50 cm, where the water circulation is very intense);
- below 60 and 90 cm deep, there is a transitional area with a soil moisture that is 10% lower than in the upper layer. At depths that exceed 100 cm, the moisture is no longer influenced by the daily rainfall regime, but, we believe, the influence comes from the superficial phreatic layers that are placed discordantly at different depths.

By analyzing the landslide dynamics for over 20 years, the following conclusions could be drawn: the most important movements were identified during the summer, after recording the maximum amount of rainfall; if the landslides occur in clayey deposits (Buba), their velocity is lower as compared to those that occur in predominantly sandy-silty deposits (Huiduman); the highest speeds were recorded at the end of August (Huiduman) or September (Buba) (fig. 5).

The daily variations over a month or during a year of the soil moisture can be noticed in the increasing and decreasing of the geological stress, by providing a temporary overloading. These variations of precipitation were also perceived in a differentiated way in the acceleration or the decreasing of the movements on the main body of the landslide, and in the variation of the sensitivity perceived through changes in the morphology of the main body, of the crown and of the toe of the landslide. All these changes could be identified through repeated topometric elevations and geomorphological mapping (fig. 6).

CONCLUSIONS

There is a strong relationship between the amount of precipitation and the dynamics of the landslides. This relationship can be easily identified at the seasonal level, as well as yearly or on longer periods of time. The physical and the mechanical characteristics of the slope deposits are those that «filter» rheologically the future reaction.

Daily precipitation does not represent a triggering factor for landslides, it only facilitates a certain dynamics in the evolution of the landslides. By taking into consideration the observations we have made so far, we believe that

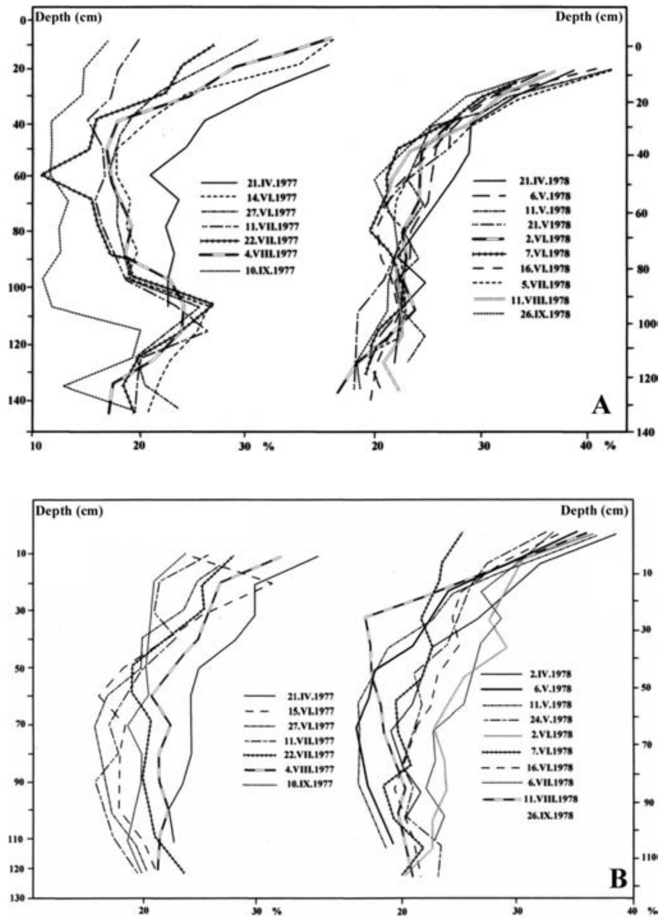
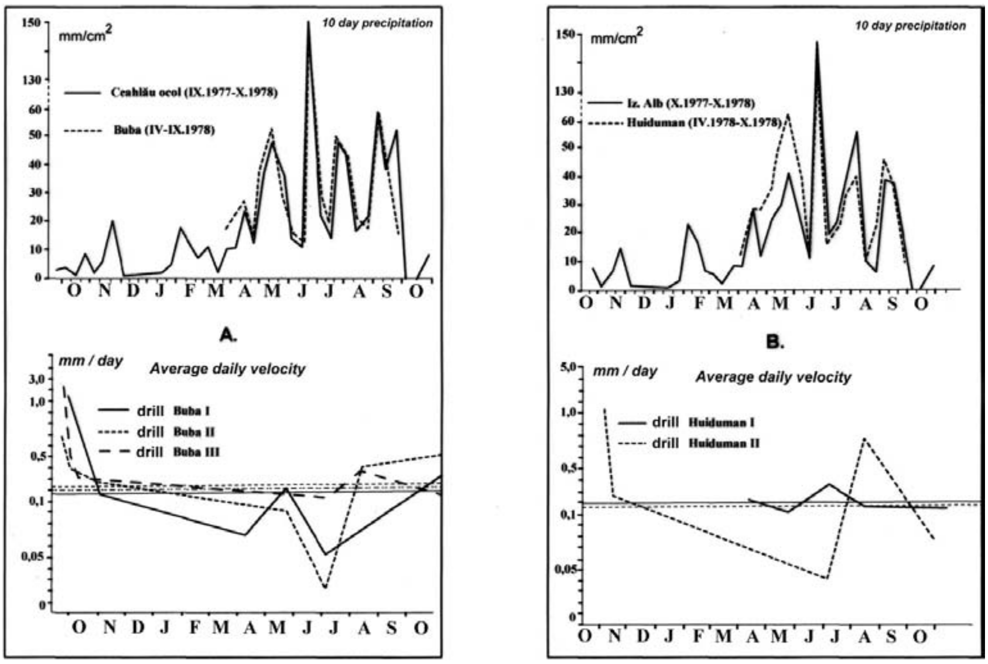


FIG. 4 - Variation of the soil moisture in the Huiduman (A) and Buba (B) landslide catchments.

FIG. 5 - Differences in landslide velocity (obtained through inclinometric measurements in Buba and Huiduman catchments) in proportion to the amount of rainfall over a decade.



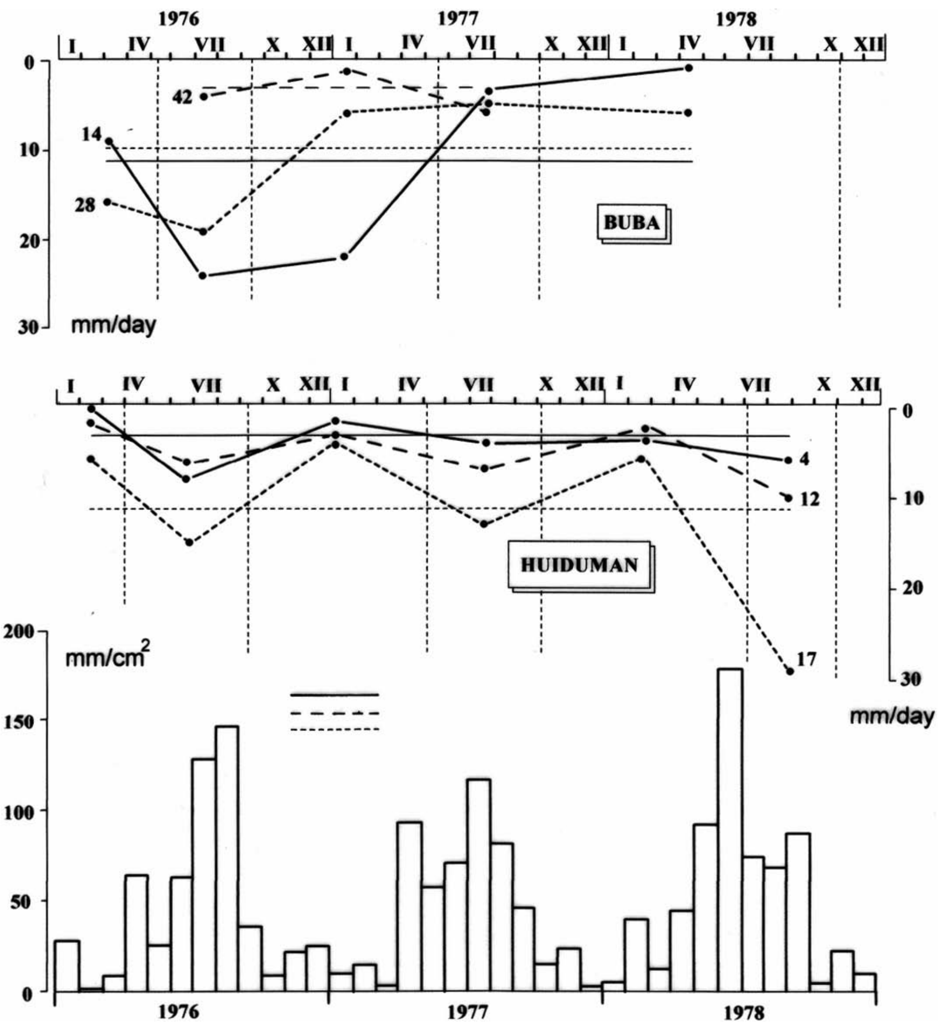


FIG. 6 - Differences in landslide velocity (obtained through topographic measurements) in proportion to monthly rainfall.

only the rainy periods that extended over seven days consecutively can trigger a temporary acceleration of the dynamics. The profound dynamics of the landslides is influenced, on the other hand, by a consecutive period of years with surplus of precipitation.

On longer periods of time there can be identified some cycles as regarding the reactivation of landslides, as well as maintaining them active. The cycle with the biggest effects in the dynamics of the slopes repeats every 30-35 years. This cycle was checked by the reactivation of the landslide from Buba in 2001 and since then, from the slopes there have been removed annually over 1000 m^3 of colluvia. It is still active nowadays.

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