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MODELLING OF LANDSLIDE-TRIGGERING FACTORS: A CASE STUDY IN THE NORTHERN APENNINES ITALY

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Figure 1. View of Valzangona Landslide

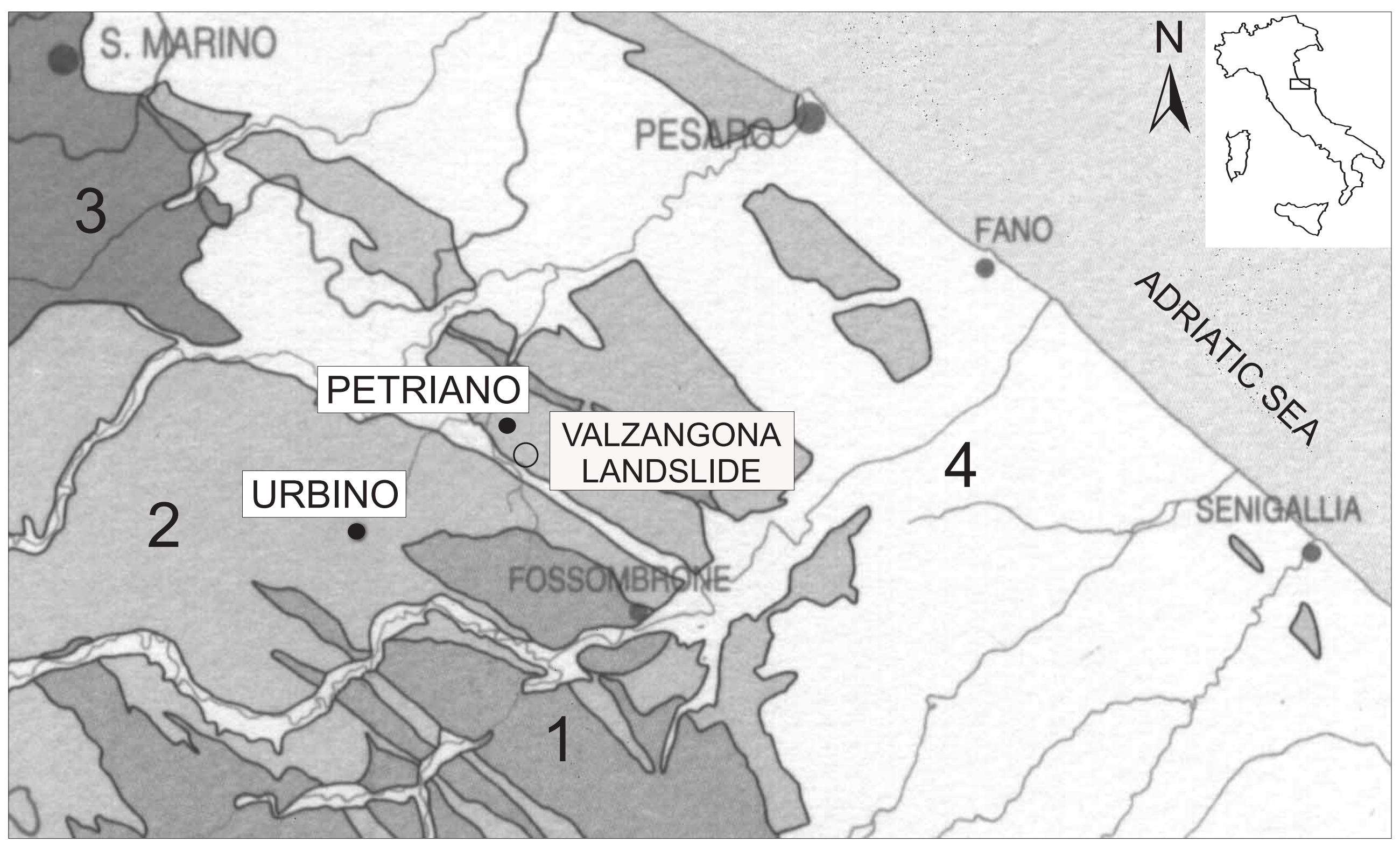

Figure 2. Geological sketch of the Urbino area. 1) Limestones, marly limestones, marlstones and cherts (formations between Calcare Massiccio and Schlier, Lias Miocene p.p.); 2) Arenites, pelites and evaporites (formations between Marnoso-Arenacea and Colombacci, Miocene p.p.); 3) Caotic complex clays of the Marecchia Valley; 4) Clayey, sandy and gravelly deposits (Plio-Pleistocene). (From Antonini et al. 1993, modified)

The poster describes a study which was conducted on a landslide-prone slope of the Northern Apennines (Italy). The slope, which dominantly consists of clayey and clayey-marly terrains, has been affected by landslide phenomena, whose frequent reactivations have involved wider and wider areas, destroying one home and causing significant damage to an important local road.
In order to analyse the correlation between rainfall and landslide reactivation, data were collected on the main stages of landslide activity and on the trends of rainfall in the same periods.
The study was expected to identify landslide-triggering rainfall thresholds, which may lead to the development of prediction, prevention and warning systems for landslide risk mitigation.

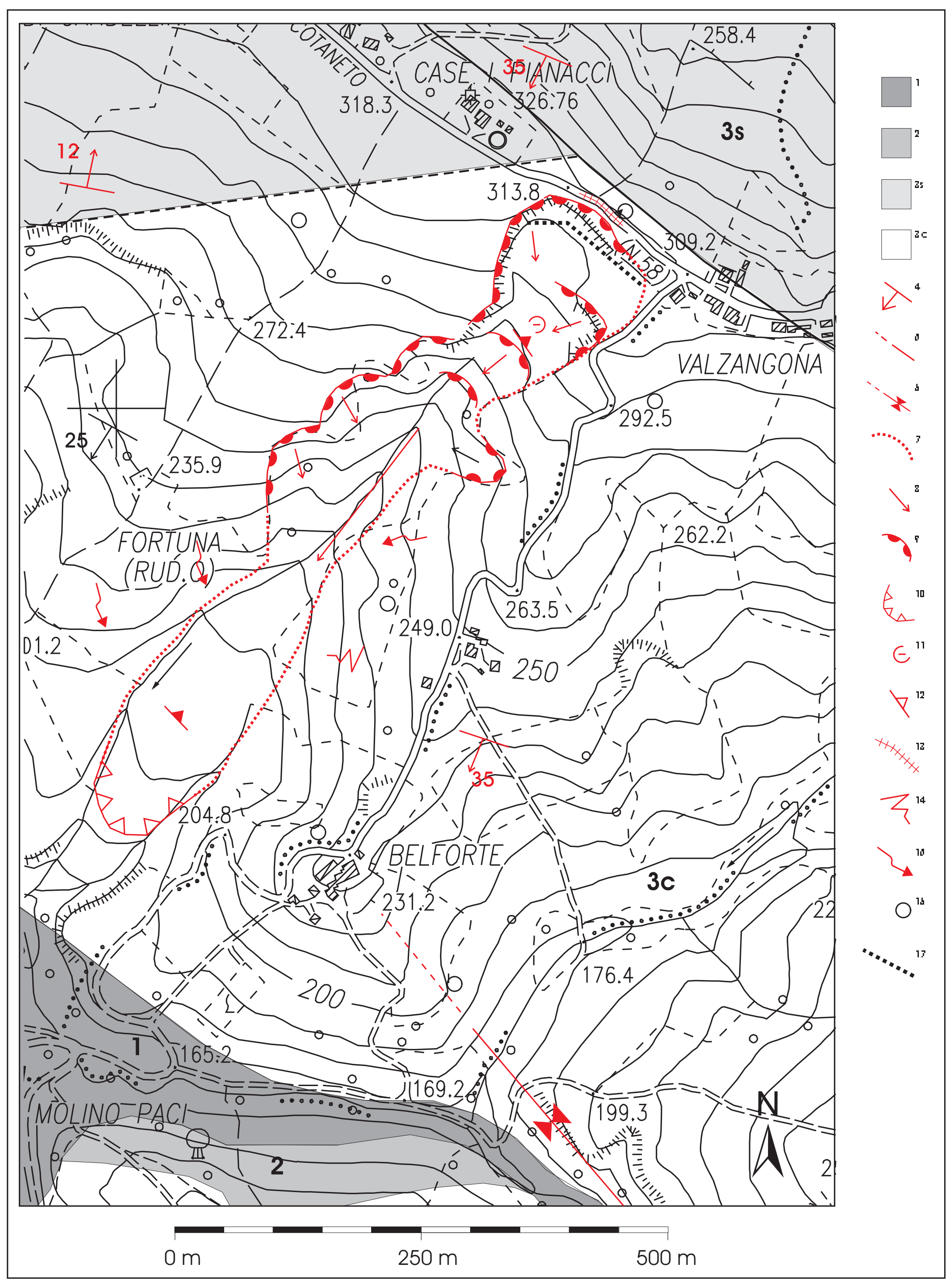

Figure 3. Geological and geomorphological sketch of the Valzangona area. 1) Present and recent alluvia (Holocene); 2) Pliocene clays (lower Pliocene); 3s) Colombacci formation sandy member (Messinian); 3c) Colombacci formation clayey member (Messinian); 4) direction and dip of strata; 5) fault (dashed line if the fault is supposed); 6) syncline axis (dashed line if the syncline axis is supposed); 7) boundary of landslide body; 8) main direction of movement; 9) landslide scarp; 10) landslide deposit; 11) depressed area; 12) counterslope; 13) tension cracks; 14) widespread runoff; 15) surface movements; 16) well; 17) gabion walls.

This poster sums up the preliminary findings from a study conducted on a training landslide-prone slope (Valzangona landslide, Fig. 1) located near Urbino, in the northern Apennines (Italy, Fig. 2) The landslide occurred on dominantly clayey soils, highly exposed to weathering.
The examination of aerial photos taken in 1955 indicated that the Valzangona landslide is the result of a dominantly erosional process at the toe of the slope, followed by successive stages of gravitational movements which started in 1981. These movements caused the retreat of the crown area of the landslide and its lateral and down slope spread. The Valzangona landslide may be classified as a complex phenomenon, featured by roto-translational movements evolving into flows in the intermediate-lower portion of the slope. The profile of the landslide is fairly irregular, with small scarps, steps, trenches and counter slopes (especially at the top, Fig. 3)
It should be pointed out that the phenomenon is still active, in spite of mitigation works (gabion walls and drainage systems); landslide reactivations cause recurrent damage to a local road and to remedial works in the crown area (Fig. 4).
The study includes the implementation of a hydrological-statistical model for the Valzangona landslide, that relies on empirical relations between hydrological variables and landslide movements: within a well-defined region and for a given type of landslide, they seek to identify threshold values of precipitation or other precipitation-derived quantities, above which instability phenomena may take place.
The model developed for the Valzangona landslide takes into account the exceptional character of the meteoric events related to landslide reactivation. For this purpose, use was made of daily rainfall data. The landslide reactivation data (Fig. 5) were retrieved from the literature, the archives of the Municipality of Petriano, other dedicated archives and daily papers.
Graphs (Fig. 6) were built to analyse the hydrological scenario preceding and accompanying landslide reactivation. They show the cumulative rainfall prior to landslide initiation (day 0) and the rainfall probability curves for different return times.

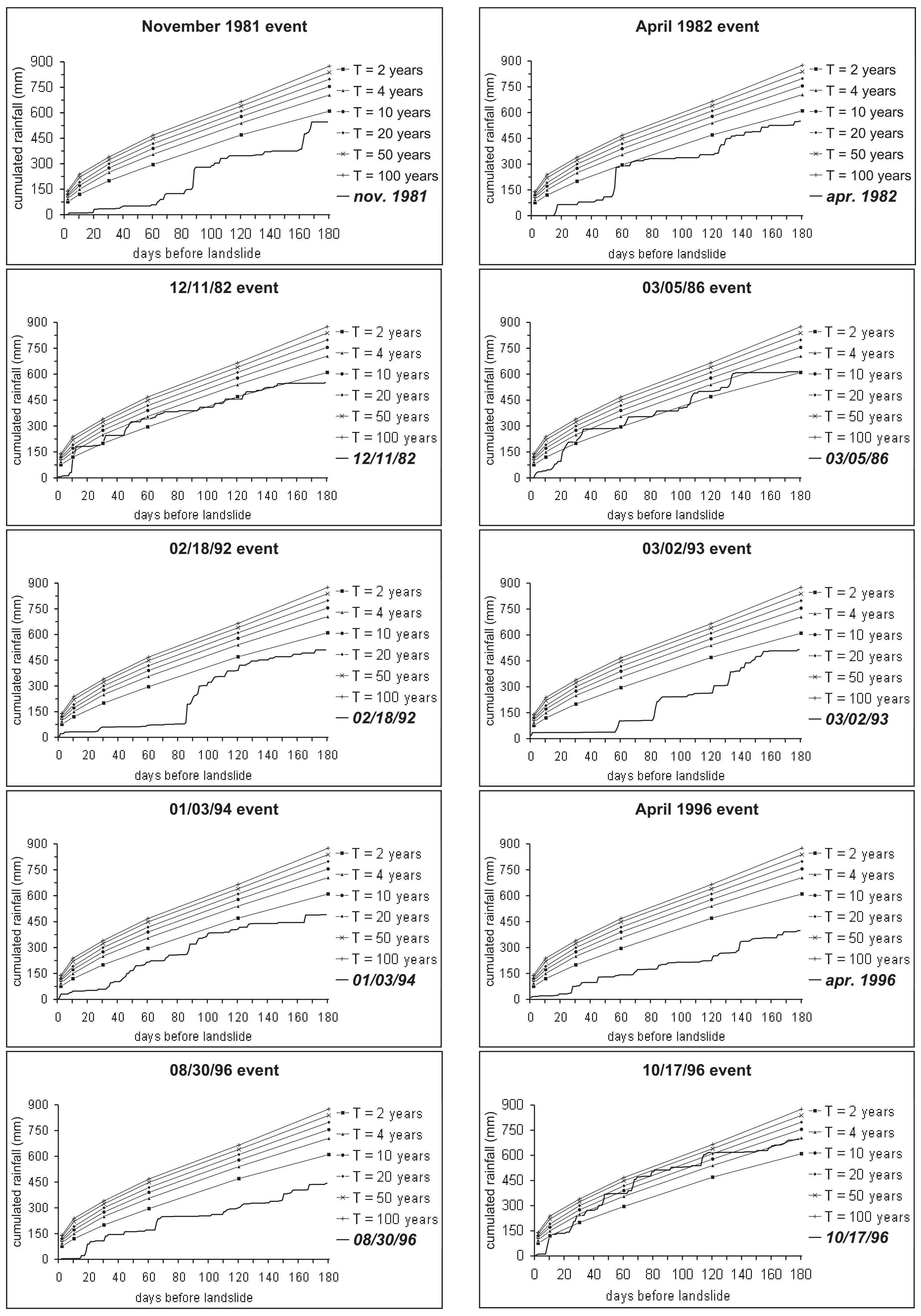

Figure 6. Comparison of cumulated rainfall curves for different return times (T) computed with the GEV function (Jenkinson 1955; Hosking et al. 1984) and of cumulated rainfall curves associated with reactivations of the Valzangona landslide (day 0).

The latter curves, i.e. a kind of "probabilistic precipitation abacus", enable to assess the return time of any cumulative curve for each reactivation and thus to estimate whether it has an exceptional character or not. They also offer the opportunity: (i) to identify rainfall events, significant in terms of quantity and duration, which did not take place immediately before the landslide, but which may have played a role in its onset; and (ii) to assess their return time with simple graphic operations.
The observations deriving from the examination of Fig. 6 are summarised in Fig. 7, which shows that the Valzangona landslide reactivations are connected to exceptional rainfall events, which occurred in periods of time even very distant from the day of initiation of the landslide.
The hydrological variable, which is significant in terms of landslide initiation, is the rainfall cumulated in short periods (3-20 days, Bold characters in Fig. 7) with high average intensity (up to 43 mm/day) and/or the rainfall cumulated during longer periods (30-135 days, Italic characters in the table).
These considerations are explained in the diagram of Fig. 8, which correlates intensity and duration of potentially landslide-triggering rainfall events. The interpolation curve drawn in the Figure is a first-cut rainfall threshold, above which the landslide may be triggered. This threshold should be validated by a deterministic model taking into account the changes in pore pressures, as a function of meteoric events not necessarily exceptional and of the effects of such changes on slope stability.

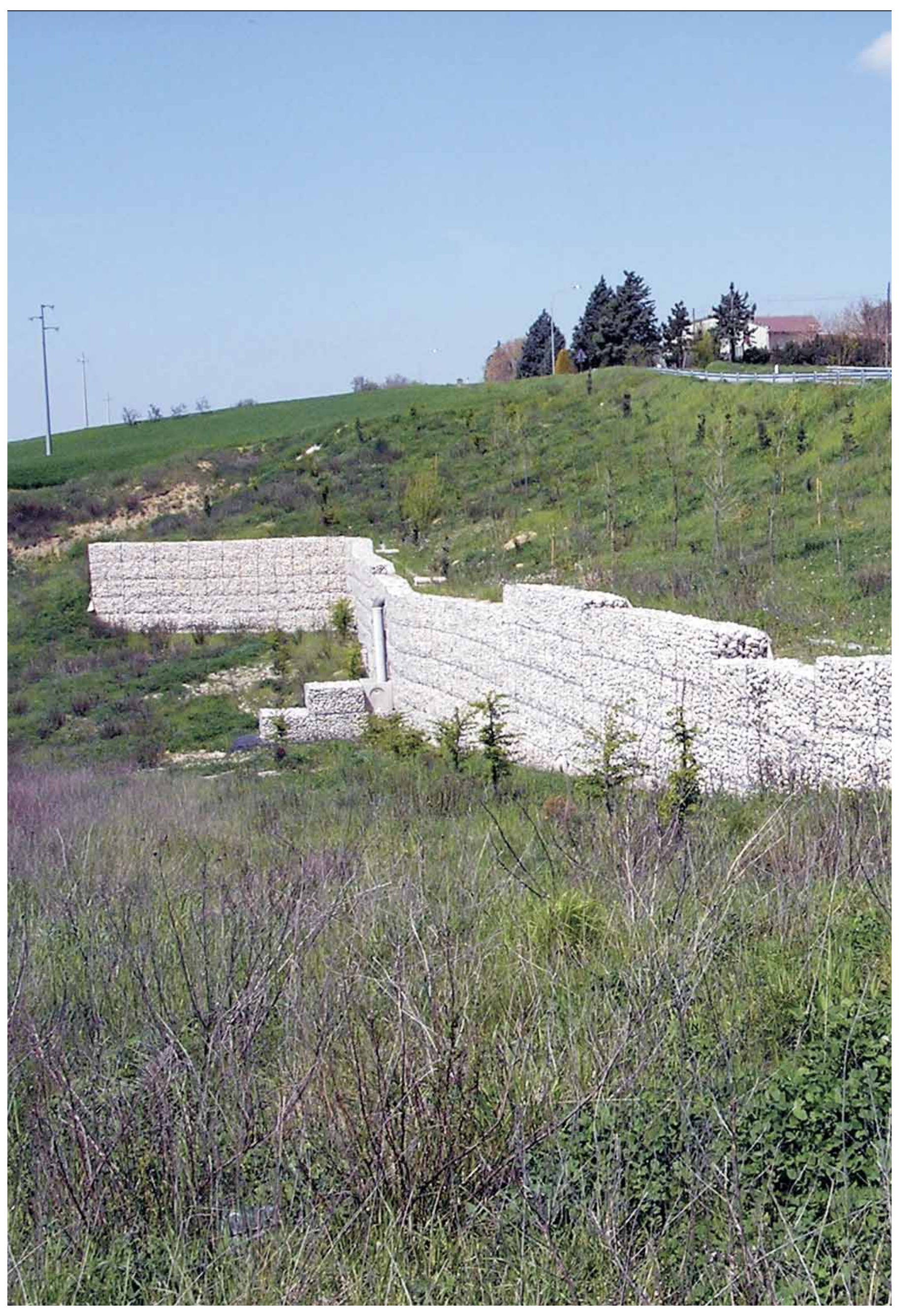

Figure 4. Remedial works in the crown area

Month	Day	Year	Source	Excerpts from the news
11		**1981**	Literature	*...first important landslide movement ...*
4		**1982**	Literature	*... landslide reactivation with earth and mud flows ...*
12	**11**	**1982**	Municipal Archives	*... reactivation after last meteoric event ...*
3	**5**	**1986**	Municipal Archives	*...further developments ...*
2	**18**	**1992**	Municipal Archives	*... reactivation after last meteoric events ...*
3	**2**	**1993**	AVI Archives	*... partial collapse of Francini's house located at the crown of the landslide ...*
1	**3**	**1994**	Literature, Municipal Archives	*... the landslide involved the road and the house located at its crown ...*
4		**1996**	AVI Archives, daily paper	*...Francini's house completely destroyed ...*
8	**30**	**1996**	Municipal Archives	*...reactivation after last meteoric events ...*
10	**17**	**1996**	Municipal Archives	*... road cracks after recent rain ...*

Figure 5. Historical news on reactivations of the Valzangona landslide.

Landslide event	D(*)	Q	T	I=Q/D
30(?) Nov. 1981	*30(59-89)*	*228*	*2-4*	*7.6*
	3(86-89)	**130**	**50**	**43**
30(?) Apr. 1982	*59(0-59)*	*290*	*2-4*	*~5*
	6(53-59)	**181**	**>100**	**30**
11 Jan. 1982	**12(0-12)**	**178**	**10**	**~15**
	5(7-12)	**165**	**50-100**	**33**
5 Mar. 1986	*35(0-35)*	*281*	*4-10*	*~8*
	135(0-135)	*604*	*4-10*	*~4.5*
18 Feb. 1992	**20(84-104)**	**272**	**50-100**	**13.6**
	46(84-130)	*367*	*10*	*~8*
2 Mar. 1993	*32(56-88)*	*204*	*2-4*	*~6*
	7(81-88)	**135**	**10**	**~19**
3 Jan. 1994	20(32-52)	135	<2	~7
30(?) Apr. 1996	8(26-34)	60	<2	7.5
30 Aug. 1996	**7(14-21)**	**98**	**4**	**~14**
17 Oct. 1996	*82(0-82)*	*512*	*50*	*~6*
	4(7-11)	**118**	**10**	**~30**
	40(7-47)	*368*	*50*	*~9*

Figure 7. D (days): duration of potentially landslide-triggering rainfall events, (*) period when the rainfall event occurred, calculated backwards starting from landslide initiation (day 0); Q (mm) = quantity of rainfall; T (years) = return time; I (mm/day) = average intensity.

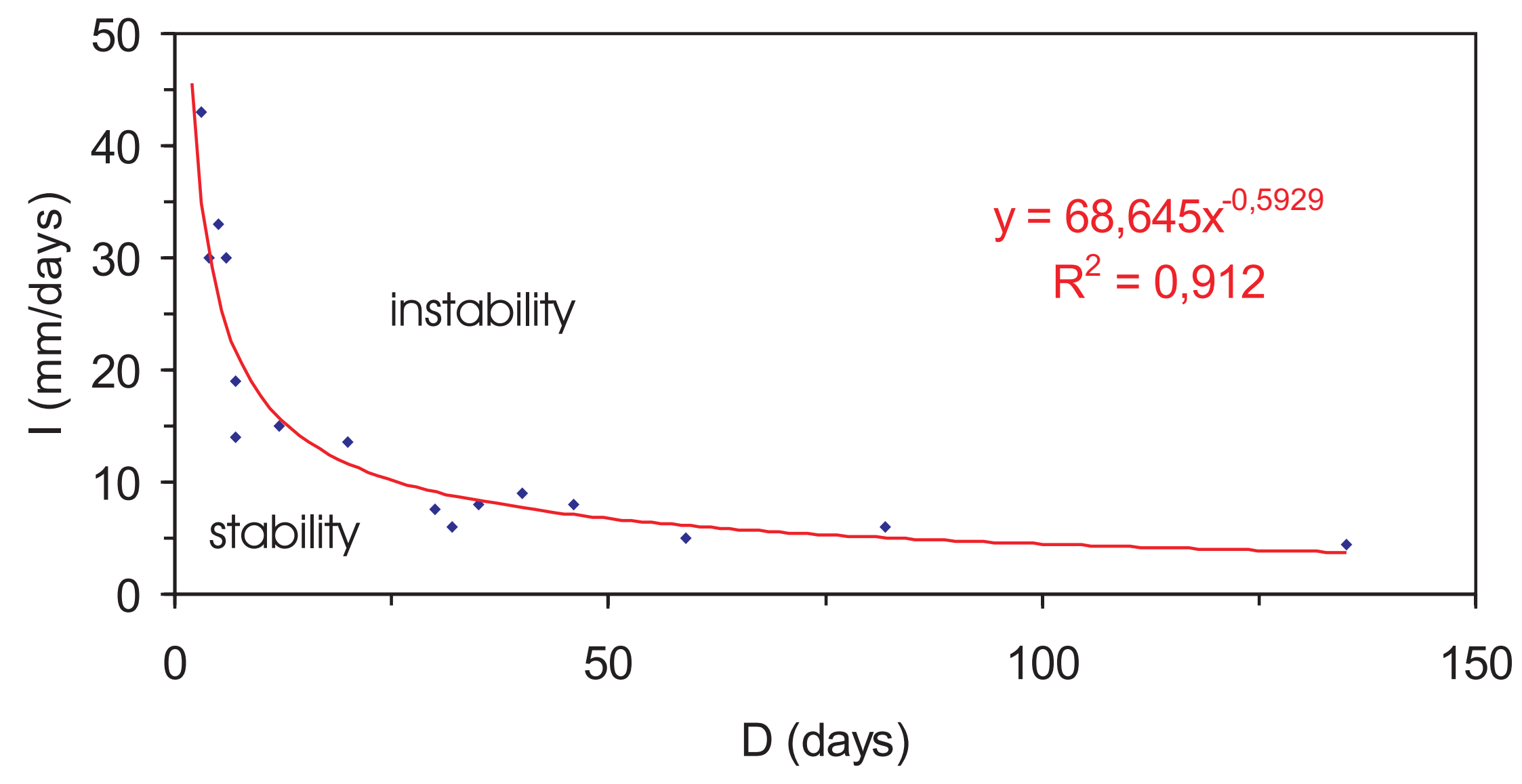

Figure 8. I-D diagram of potentially landslide-triggering rainfall events.

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