THE REACTIVATION OF ANCIENT LANDSLIDES IN THE EMILIA-ROMAGNA REGION (ITALY): RISK-REDUCTION STRATEGIES

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Abstract: In Emilia-Romagna, over 70.000 landslide bodies cover one fifth of the hilly and mountainous territory. The majority of them originated as earth-flows after the last glacial maximum and grew during the rainiest periods of the Holocene through the superimposition of new earth flows. These ancient landslide bodies still represent a threat. In fact, in the Emilia-Romagna Apennines as well as in the entire Northern Apennines, almost all the present-day landslide activity is due to the reactivation of them. Consequently, territorial planning and geo-thematic cartography are fundamental tools for the reduction of risk. Emilia-Romagna geo-thematic cartography (1:10.000) is legally binding and regulates land use in regional, municipal and basin plans.

INTRODUCTION

The Emilia-Romagna Apennines are the portion of the Northern Apennines under the administration of the Emilia-Romagna Region (approximately 12.000 km²), corresponding to the northern flank of the chain.

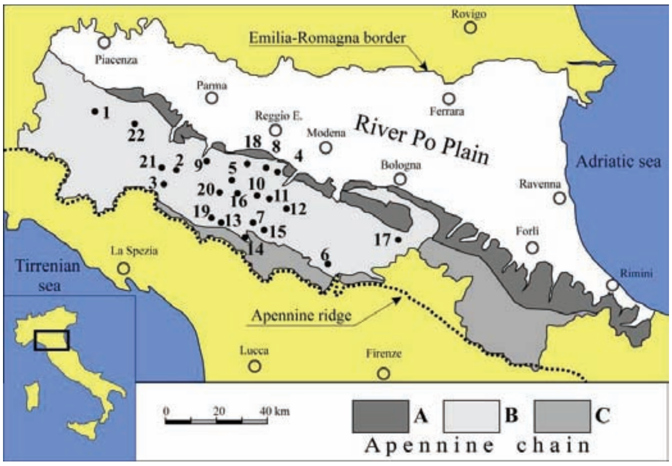

Figure 1 Emilia-Romagna landslide susceptibility (see text) with location map. Location of landslides cited in the text:
1- Velleia; 2- Signatico; 3- Corniglio; 4- S.Romano; 5- Lavina di Roncovetro; 6- Gaggio Montano; 7- Morsiano; 8- Casoletta; 9- Provazzano; 10- Magliatica; 11- Cà Lita; 12- Morano; 13- Cerrè Sologno; 14- Febbio; 15- Boschi di Valoria; 16- Cavola; 17- Cà di Sotto; 18- La Vecchia; 19-Cervarezza; 20- Groppo; 21- Costa di Casaselvatica; 22- Casa Ravera.

In the Emilia-Romagna Apennines the Regional Geological Survey has identified over 70.000 landslide bodies, covering one fifth of the 12,000 sq. km. territory. From the morphological point of view, a good 90% of them are large, ancient earth flows.

Ancient dormant earth flows have been areas wrongly judged as suitable for human settlement since ancient times, thanks to the low slope of their frontal and mid-accumulation zones, a real trap for many hamlets and villages (e.g. the Morsiano case, Figure 9). As a result, 281 inhabited centres (defined as four or more buildings, excluding "scattered houses") lie upon or are directly affected by active landslides and 1608 by dormant landslides. Dozens of municipal centres are among them.

Figure 2. The ancient Signatico earth flow in Val Parma resumed activity in 879, 1710, 1836, 1879, 1896, 1901, 1905, 1906, 1945, 1947, 1948, 1949, 1957 1977 and 1999. In consequence of 1836, 1879, 1896 and 1945 events, it obstructed the valley floor and large lakes formed. Photo by Bertolini G., 2006.

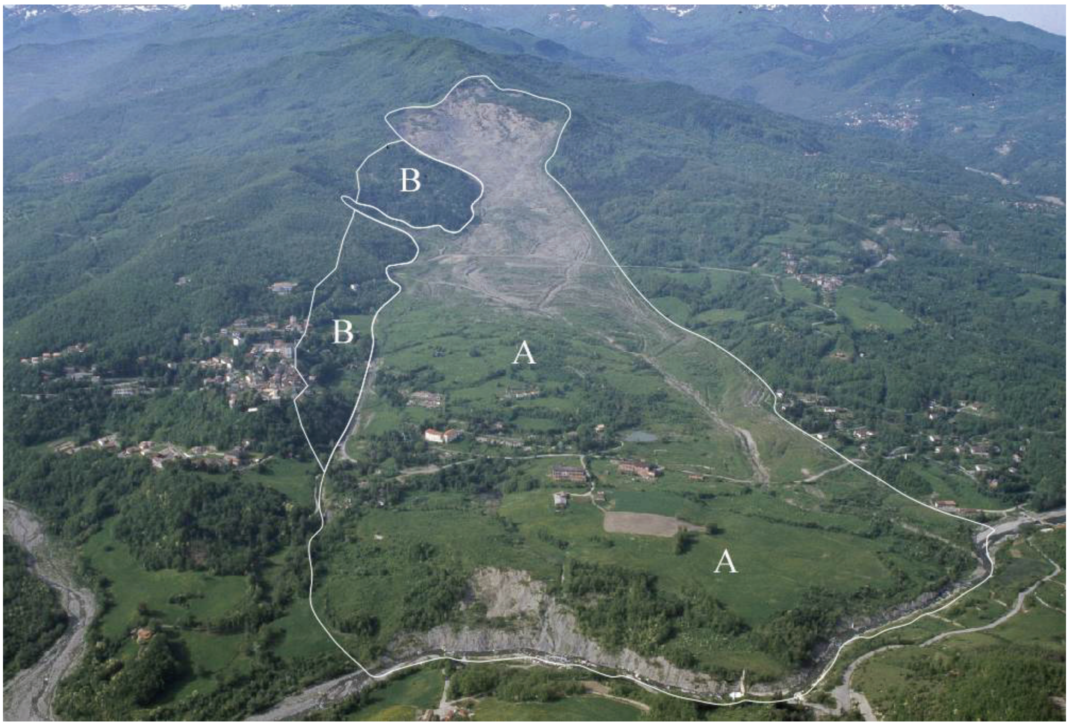

Figure 3. The Corniglio landslide. The “Lama” (A) reactivated in 1994, after one century of dormancy and remained active until 2000, destroying 70 edifices. “B” indicates parts of the slope affected by deformations and movements that were caused by the friction of the left flank of the lama. Photo by Bertolini G., 2006.

A good 16% of the total road network is on top of existing landslide bodies, and so is threatened and periodically affected by slope movements.

It is demonstrated that about the 90% of damage caused by landslide activity in Emilia-Romagna derives by reactivation of already existing landslide bodies, mainly ancient earth flows that are the direct object of this paper

The cost of this situation is staggering: in Emilia-Romagna, over the last five years about 390 million Euros has been invested in reconstruction, relocation of villages, consolidation work and monitoring of unstable slopes. Luckily, the number of human casualties caused by reactivation of earth flows in Emilia-Romagna is almost negligible, thanks to the generally slow displacement velocity of this type of landslides.

Landslide susceptibility in Emilia-Romagna Apennines

According to the regional 1:25.000 *Landslide Susceptibility Map* (Bertolini *et al*. 2002), geological units show a predisposition to instability that may be quantified on the basis of the "Landslide Density Index". LDI represents the ratio between the sum of landslide areas affecting a given geological unit and its total mapped surface.

The Romagna sector and the Apenninic ridge above 900 m elevation are formed by Oligo-Miocene sandstones (e.g. the "Macigno" and the Marnoso-arenacea Formations, "C" in Figure 1) with a value of the "Landslide Density Index" (LDI) ranging from 1 to 10 % (low susceptibility).

Medium susceptibility units (Plio-Pleistocene "Blue Clays" and "Yellow Sands" with and LDI from 10 to 20%) form the Apennine foothill (A in Figure 1).

In the remaining part of Emilia Apennines, shaly formations with high susceptibility (LDI from 20 to 40 %) prevail: olistostromes, "broken formations" with block-in-matrix structure ("Argille Scagliose" Auctt.), mainly Cretaceous in age ("B" in Figure 1).

As regards the relationship between morphology and susceptibility, the majority of landslides are concentrated in areas where the slope gradient ranges from 8 to 11° (Bertolini & Pizziolo 2006), that is the usual slope angle of "Argille Scagliose" and similar formations, whereas in slopes whose gradients exceed 25° they are very rare, thanks to the presence of a stronger bedrock.

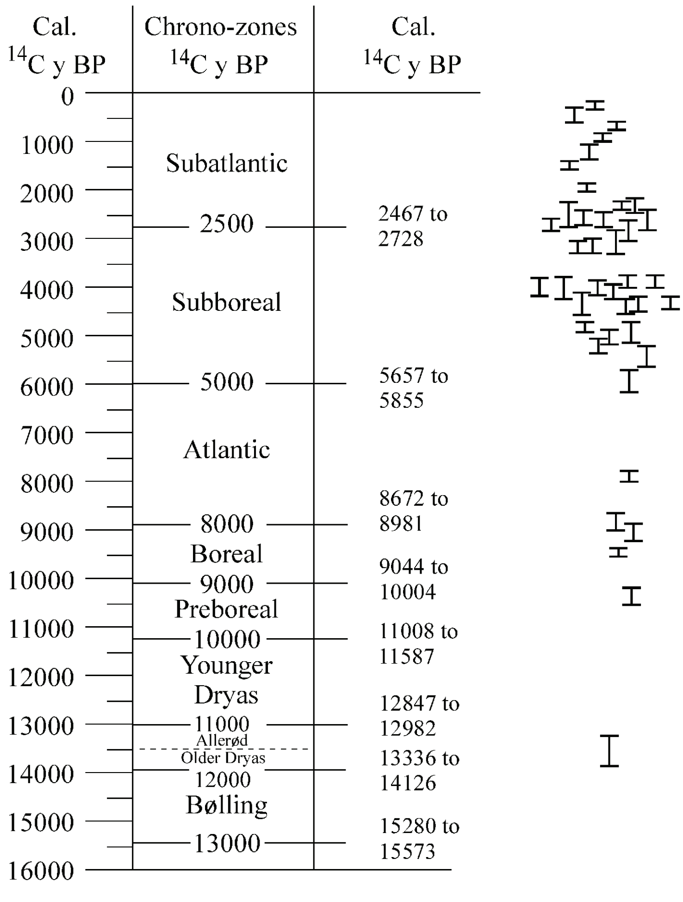

Figure 4. Temporal distribution of the landslide events from the Late-Glacial to the present in the provinces of Reggio Emilia, Modena and Parma. Samples collected by G. Bertolini, 1994 – 2002.

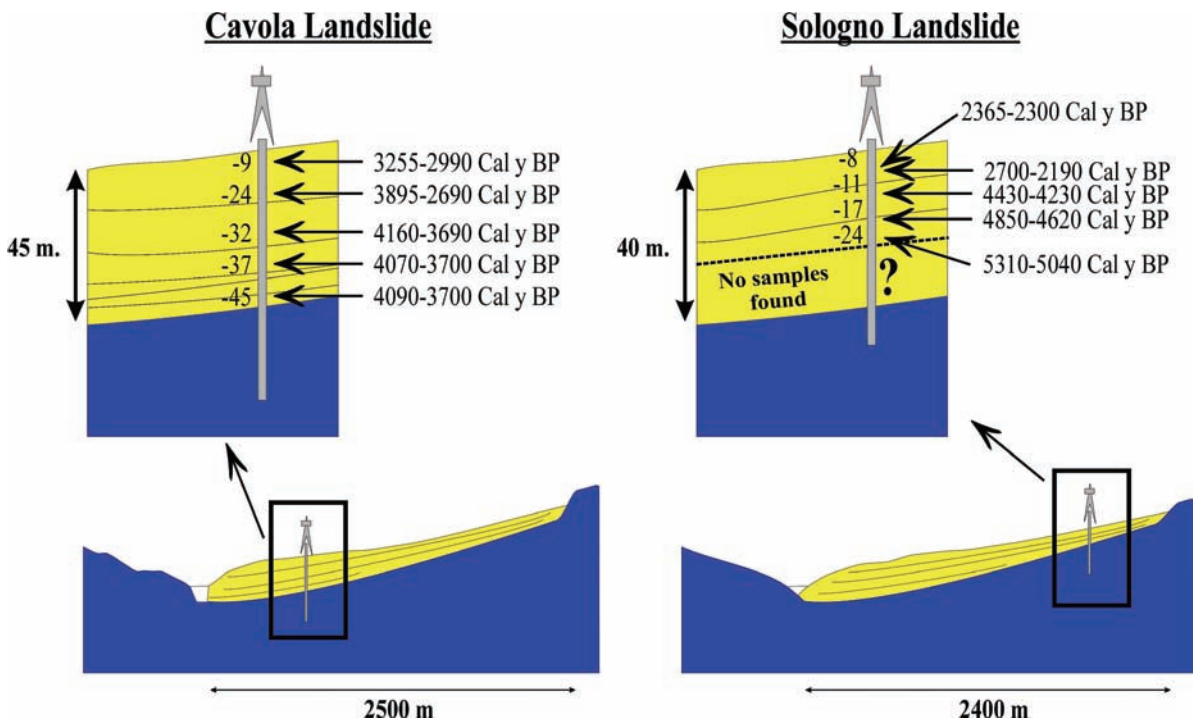

Figure 5. The series of the ^{14}C samples found inside two different landslide bodies (Cavola on the left and Sologno on the right). Their age grows accordingly with the sedimentation rules: the more the depth, the more the age.

Features and origin of ancient landslides

As regards dimensions, it may be calculated that at least 4000 landslides have an amplitude exceeding 10 hectares and 100 exceeding a square kilometre. Several of them exceed 4 km in length.

From plan view, they show the typical features of a earth flow: a large crown, a relatively narrower middle "channel" -corresponding to the area of flow- and a wide basal fan reaching the valley floor, with a modest or null slope inclination (es: the Signatico landslide, Figure 2).

The thickness of them is usually no more than a few tens of metres. Calculations based on a sample of 46 different landslides (whose movements are monitored by 190 inclinometers) show that the majority of them (52%) reaches a depth ranging from 10 to 30 meters. About 10% of them show a depth exceeding 40 m. The landslide depth has seldom reached the order of magnitude of one hundred metres, as in the Corniglio case (Larini *et al*. 2001).

These landslide bodies were -and are- nourished from several and different units (often "Argille Scagliose" or other shaly and structurally complex formations) that constitute the bedrock of the whole versant. Following sedimentological laws, their internal structure shows several superimposed "strata" taking origin in different moments of the past and from different parts of the versant. Consequently, their lithology is extremely variable and usually characterised by a block-in-matrix structure, with a prevalence of clay matrix produced by the softening of shaly units.

In terms of shear strength properties, these materials show a high degree of variability, both spatially and temporally, which is difficult to quantify.

Figure 6. The long "*Lavina di Roncovetro*" is permanently active

The minimum shear strength values are found in argillaceous materials with montmorillonite minerals (for example, *Argille di Viano Formation*; Bertolini 2001).

The Regional Authority (Bertolini *et al.* 2004 and 2005) and the University of Parma (Tellini 2004) have applied Radiocarbon Dating techniques to wood remnants collected by core boring inside the landslide bodies. These studies, carried out on several tens of landslides, demonstrate that these lithosomes are the result of multi-phase events occurring over a period of thousands of years (Figure 4). The majority of them originated as earth-flows after the last glacial maximum and grew during the rainiest periods of the Holocene through the superimposition of new earth flows. Consequently, inside the landslide body, the age of wood remnants grows with the increasing depth (Figure 5).

They evolved through phases of rapid growth and others with minor activity, like the one that we are experiencing today. Some past accumulation rates describe a landscape dynamism that is unequalled today (e.g.: 4,5 cm/year for a time period of 1000 years in the case of Cavola and ~1 cm/year for 2800 years in the case of Sologno).

Ancient earth flows as risk factors

In this paper, the term "ancient" is used for those landslides that originated from a few hundreds to many thousands of years ago (probably under different geomorphic and climatic conditions) and whose deposits are still existent. They represent the greater part of the large landslide bodies lying on the Apenninic slopes. We can consider them as the legacy of the worst climatic periods, but, in spite of their ancient origin, they cannot be considered inactive or "relict". In fact, in many cases they still represent a threat because of the possibility of reactivation.

One third of the landslides included in the regional Landslide Inventory Map (LIM) were described as “active” or “suspended” at the moment of the survey (1980-2000) while the remaining two thirds were “dormant” (in the meanings given by Cruden and Varnes 1996).

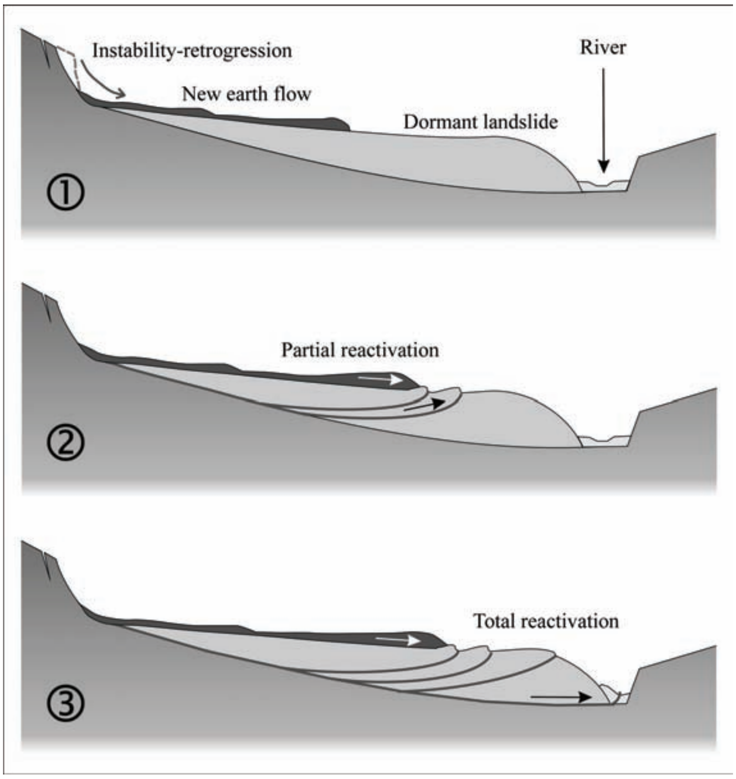

Figure 7. Reactivation often occurs through recurring behaviour:
1- surcharge and increase of pore pressures
2- formation of imbricate fissures in the upper-mid section
3-progressive failure by valleyward propagation of imbricate fissures

For practical purposes, these terms (descriptive and strictly related to the moment of observation) do not describe the present propensity to reactivate and the hazard posed by these landslide bodies.

Few landslides are perpetually active (e.g. the Lavina di Roncovetro, Bertolini & Pellegrini 2001), while the majority of them alternate periods of activity with periods of dormancy lasting from a year to a century. Longer periods of dormancy cannot be denied a priori, because of the lack of historical memories.

A comparison of these different behaviours indicates the main problem caused by anthropic factors and urban management: the longer the dormancy period (the Corniglio example, Figure 3), the more people have erected buildings and structures upon the landslide body. If landslide reactivation occurred more frequently (Roncovetro, see Figure 6; Signatico, see Figure 2), the more people were aware of the danger and avoided building.

In conclusion, in terms of territorial management, our main problem lies with those landslides that display long resting periods. The large Corniglio landslide (Figure 3) is the most obvious example: it was deceptively safe until complete reactivation in 1994 after nearly a century of dormancy. In the Seventies the old medieval village -which stood in a relatively safe position, out of the main landslide body- expanded toward the dangerous part of landslide: in 1902 only ten edifices were exposed to risk, in 1994 this number had increased to 70.

The reactivation of ancient earth flows

A recurring behaviour can be seen in the majority of reactivations of ancient earth flows that have occurred during the last decade.

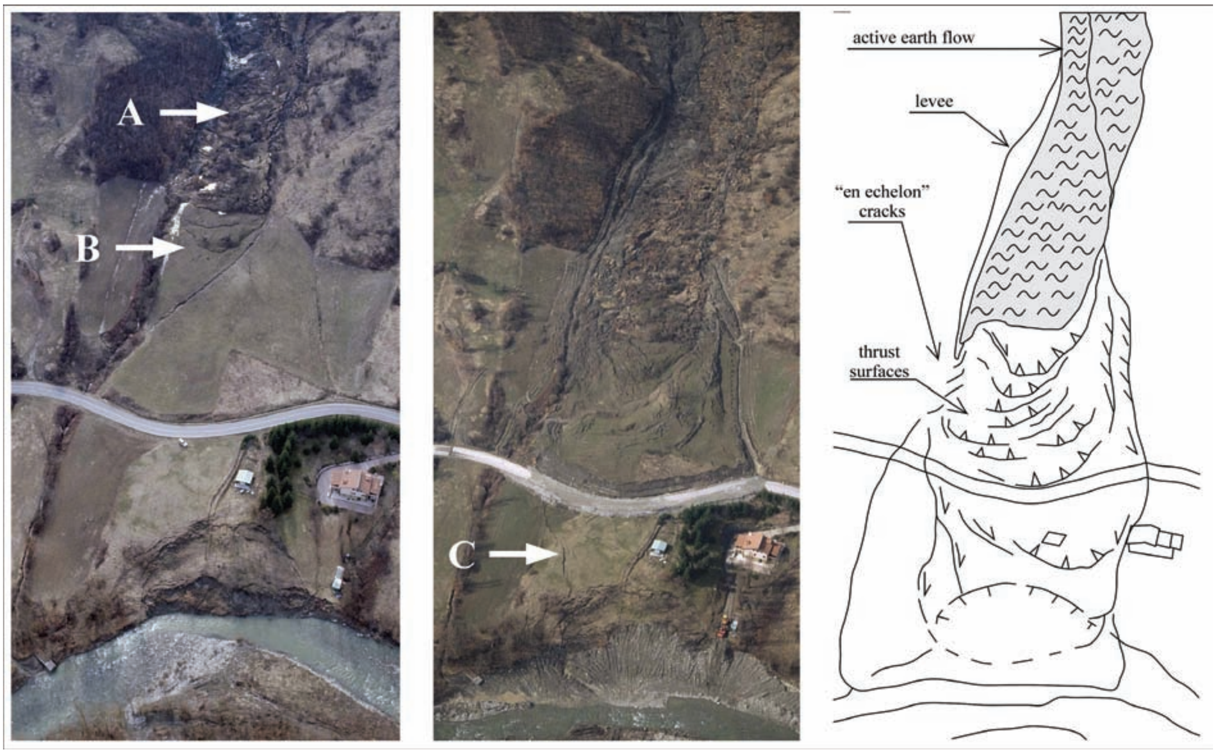

Figure 8 – The Morano landslide reactivation. These photos show two different moments of the progressive failure. Left (5 March 2006): the new earth flow (A), coming from the main scarp (not visible in these photos), reaches the mid section of the dormant landslide and triggers a series of imbricate and arcuate thrusts (B). After 15 days the net of shear surfaces reaches the toe of the landslide (C), whose sliding displacements are now of about 1 m/day (right). After further 5 days the movement suddenly stopped. Photos by Bertolini G., 2006.

In many documented or observed events, when a reactivation occurs, the first movements are large rotational slides in the source area that cause a regression of the main scarp, which is the most instable part of the versant (Figure 7). The displaced material reaches a liquid state of consistency, thus producing earth/mud-flows moving downward as far as the landslide body's mid-section. The undrained overload induces a sudden increase in porewater pressures, thus triggering a series of imbricate thrust surfaces connected to the basal slip surface of the entire landslide body. This pattern migrates valleyward, propagating progressive failure along the base of the ancient landslide, which may entirely reactivate by sliding. The activation of new thrust surfaces downhill triggers the relative deactivation of those uphill.

The multiplication of slip surfaces and cracks may sometimes lead to a complete disorder of the mass, but complete reactivation by flowing is a rare eventuality limited to shallow landslides (usually < 5 m) and to the superficial layer of larger ones, as in the Corniglio case (Larini et al., 2001).

This sequence of events, with many variations and sometimes only partially, was observed in many recent cases: Corniglio (both in 1902 and in 1994 events, Costa di Casaselvatica, Casa Ravera, S. Romano, Magliatica, Lavina di Roncovetro, Boschi di Valoria, Casoletta, Morano, Cerrè Sologno, Cà Lita (Bertolini & Pellegrini 2001; Figures 8 and 10).

In a few cases, the movement led to a significant advancement of the toe (e.g., 28, 56 and 400 metres respectively in the Corniglio, Cerrè Sologno and Cà Lita cases -Larini et al, 2001, Bertolini & Pellegrini, 2001, Borgatti et al., 2005).

In the great majority of cases, the movement comes to a stop in few months.

The Corniglio and Boschi di Valoria cases represent an exception: the first returned to dormancy after about six years of activity, the second is still active after six years after the reactivation.

During the reactivation of the main landslide body other recurring features and behaviours may be observed:

- despite the *block-in-matrix* internal structure of the landslide, a layer evidently enriched in highly plastic clay appears on the main shear surfaces; this almost impermeable layer, some 1-2 cm thick, is evident during the movement and -as exposed to external elements- is rapidly weathered after a few days;
- accordingly to Skempton (1964) and Calabresi and Scarpelli (1985), this layer shows an “anomalous” natural water content (*Wn*): in the Casoletta case, laboratory tests measured a *Wn* higher than 30% with respect to landslide material (Bertolini, 2001);
- accordingly to Baum et al. (2003), the reduced shear strength of this clay layer “helps to perpetuate movements” on surprisingly gentle slopes;
- again in accordance with the afore-mentioned authors, observations of active events demonstrate that even where (and when) landslide material reaches a sufficiently degraded state of consistency as to produce an actual earth flow, the prevailing type of movement nonetheless remains a sliding advancement along the basal surface, which appears notably striated; the significant internal deformation, on the other hand, is produced by a multiplicity of less persistent but pervasive slip surfaces; in this case, elongated ridges (or “levees”, Baum et al., 2003) tend to form along both flanks of the earth flow, ascribable to alternating rates of movement, with slowing, dilation and relevant accumulation of material, followed by an intensification of movement within a narrower “channel”.

Total reactivations are rare but usually catastrophic for properties while partial ones, more common, are less dangerous. In very few cases, the velocity is “very or extremely slow”: infrastructures and villages lying on the moving part of the landslide can survive with slight damage (e.g. the Gaggio landslide in the Province of Bologna).

The threat to human life produced by reactivation of ancient landslides can usually be managed thanks to the many precursory signs that became evident years, months or weeks before the triggering.

Figure 9. The Morsiano village, lying on a large landslide, symbolises the risk related to ancient landslide bodies. Despite its age (a wood sample found inside it dates back to 13.500 Cal. years B.P) the landslide is still active in several portions, threatening and damaging the village. Reactivations occurred in 1631 (partial), 1651 (total), 1880 and 1959 (partial). Similar situations are quite common in

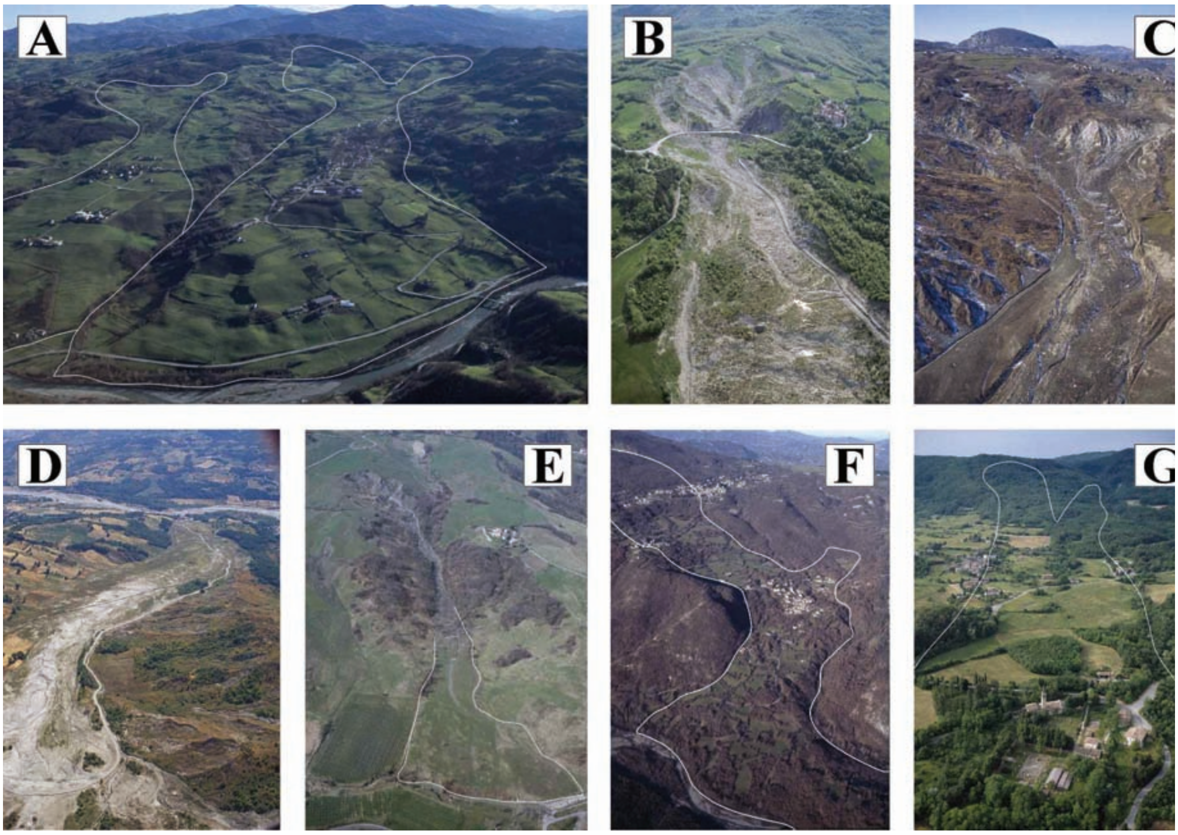

Figure 10 Some example of earth flows in Emilia-Romagna. All these landslides can be defined "ancient" (they originated thousands of years ago) but they still represent a threat because of the possibility of reactivation (accordingly to the meaning adopted in this paper). A – The Cavola and L'Oca Landslides; B - The Costa di Casaselvatica Landslide; C – The Cà Lita Landslide crown, viewed from the valley; D – The Cà Lita Landslide mid and lower portion, viewed from the crown; E – The "LaVecchia" Landslide; F – The large Cervarezza Landslide, now dormant, which reactivated in 1472, 1560, 1697, 1714 and 1936, damaging and destroying several times the villages lying on it; G – The long Velleia Landslide where an ancient roman town, in foreground, lived without evident damages from the I century B.C. to the IV century A.D. Aerial photos by Bertolini G., 2006.

Causes of reactivation

Long-lasting rainfalls play a major role as triggering factors in reactivating landslide bodies during the whole year, while the melting of snow cover is particularly effective in the months of March and April (Basenghi & Bertolini 2001)

Among the triggering causes of the Emilia Apennine landslides, earthquakes should not be overlooked, although seismic triggers have seldom been identified with certainty.

River damming occurrence

Many cases of recent and historical river damming are recorded in the regional Data Base.

The most considerable case in recent times took place in 1960 in the Secchia valley (Reggio Emilia Province): the so-called "Cerredolo Lake" (Bertolini & Pellegrini, 2001) attained a maximum volume of 26.000.000 m^3. Other huge lake, four kilometer long, formed after the 1714 Cervarezza landslide reactivation (Figure 10). The landslide of Signatico (Figure 2) obstructed the river floor in 1836, 1879, 1896 and 1945.

None of these ancient or recent lakes today exists: usually, the river erodes the landslide obstruction in few months or, at maximum, in several years, as in the 1945 Signatico event.

Consolidation works

In Emilia-Romagna, regional and local authorities perform a great number of consolidation works. As already stated, over the last five years about 390 million Euros has been invested in reconstruction, relocation of villages, consolidation work and monitoring of unstable slopes.

Usually these interventions are not preventive but subsequent to reactivation events. Sometimes, the relocation of villages is judged the best risk-reduction strategy, as in the recent case of the hamlet of Poviglio, which was damaged four times in the past century.

Consolidation works are usually performed after the event and in this case they cannot properly be considered as a "strategy" but a necessity. In other words: when a consolidation work is needed, the risk-reductions strategy has already failed, as in Emilia-Romagna too many times occurs.

TEMPORAL FORECASTING FEASIBILITY IN DORMANT EARTH FLOWS

Time-series analysis methods

Uncertainty about geological and hydro-geological parameters minimizes the reliability of deterministic methods for forecasting purposes, like stability analyses.

The main obstacle is the variability in space and time of geomechanical parameters (i.e.: progressive failure) and the continuous changes in pore waters pressures brought about by external (precipitation, snow melting) or internal (overload, local stresses, nourishment from subsoil waters) factors.

In recent years, many researchers have applied the time-series analysis of rainfalls (the most usual triggering cause), using even statistical methods, with the aim of formulating forecasting models of the "black-box" type. Also in Emilia-Romagna several studies aimed to obtain triggering thresholds from real events (e.g. Bertolini & Pellegrini, 2001, Lollino et Al, 2001). Many experiences are based on the usual empirical relationship between rainfalls and landslide behaviour.

Lollino et Al. (2001), in the case of Corniglio, emphasises the role of the pattern of precipitations (in time and space), which can bear a greater influence than the simple amount of precipitations.

Basenghi & Bertolini (2001) draw attention to the role of the melting of snow covers in reactivating a large number of landslides and underline the inadequacy of the simple rainfall time-series analysis in order to identify and quantify the triggering causes of a landslide.

So far, because of the uncertainty of results, these studies often remain of scientific interest but do not find any real application.

The problem is that the relationship between causes and effects is anything but simple. Experience teaches us that a certain ancient earth flow can reactivate under different triggering conditions as a consequence of the real distribution and magnitude of stresses inside the slope. Hidden progressive failures can be in progress for years. Internal stresses are continuously changing over time and consequently the same amount of rain (or snowmelt) can produce different effects from time to time.

Historical failure rate

In principle, if a detailed knowledge of past events exists, the probability of reactivation of these ancient landslides may be simply calculated as the inverse of the recurrence interval (the time-period between two consecutive reactivations; see also Ko Ko et al., 2005 and Wu et al., 2006) on the basis of many direct methods: multiple-date aerial photos, previous ground surveys, earth observation techniques (e.g. InSAR), absolute dating (e.g. ^{14}C methods) or review of historical data.

In the regions and countries where old, long-standing administrations (governmental or/and religious) exist, historical records represent the most promising source of data.

This is particularly true in Italy where the public administration usually offers compensation for damage caused by unstable slopes and provides funds for the consolidation of the latter. As a result of the many claims, the national and local archives contain a great number of administrative files.

A historical data-base of Emilia-Romagna Region has been compiled for about two thirds of its territory and in the near future the regional administration will complete the research covering the remaining territory. Presently, the data base contains about 6,600 landslide events pertaining to 4,700 landslide bodies.

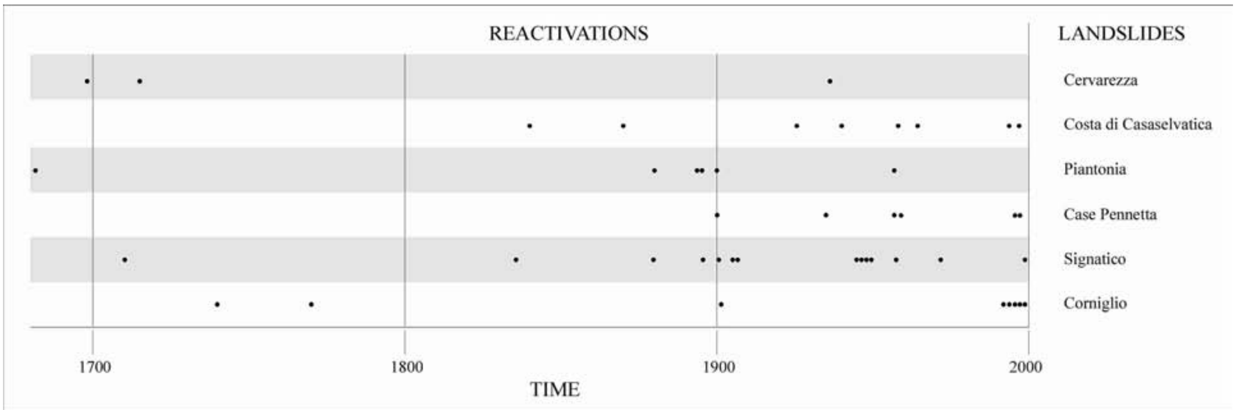

Figure 11. Recurrence of reactivation in some ancient and large earth flows, randomly selected in the data-base of historical landslide events of Emilia-Romagna.

Where available, this data-base is extremely useful when taking decisions about issuing building permits.

However, in practice, even with an exhaustive data-base of historical events, calculating the reactivation frequency for a given landslide can be a frustrating task.

The time distribution of historical events, as they appear in archive's records (e.g. in Figure 11), only partly reflects reality. These records are influenced by different factors, not always related to the evolution of the landslide activity.

For example, changes in legislation and availability of funds can lead to a proliferation of administrative files and maybe to a degree of exaggeration about the effects of the landslide.

On the contrary, dramatic events in human history such as the 1st and 2nd world wars, led to an underestimation of reality for these periods of time.

However, the main problem is related to a natural factor: the extreme variability in time of the length of the dormancy periods for each individual landslide, which is difficult to express with a simple average value.

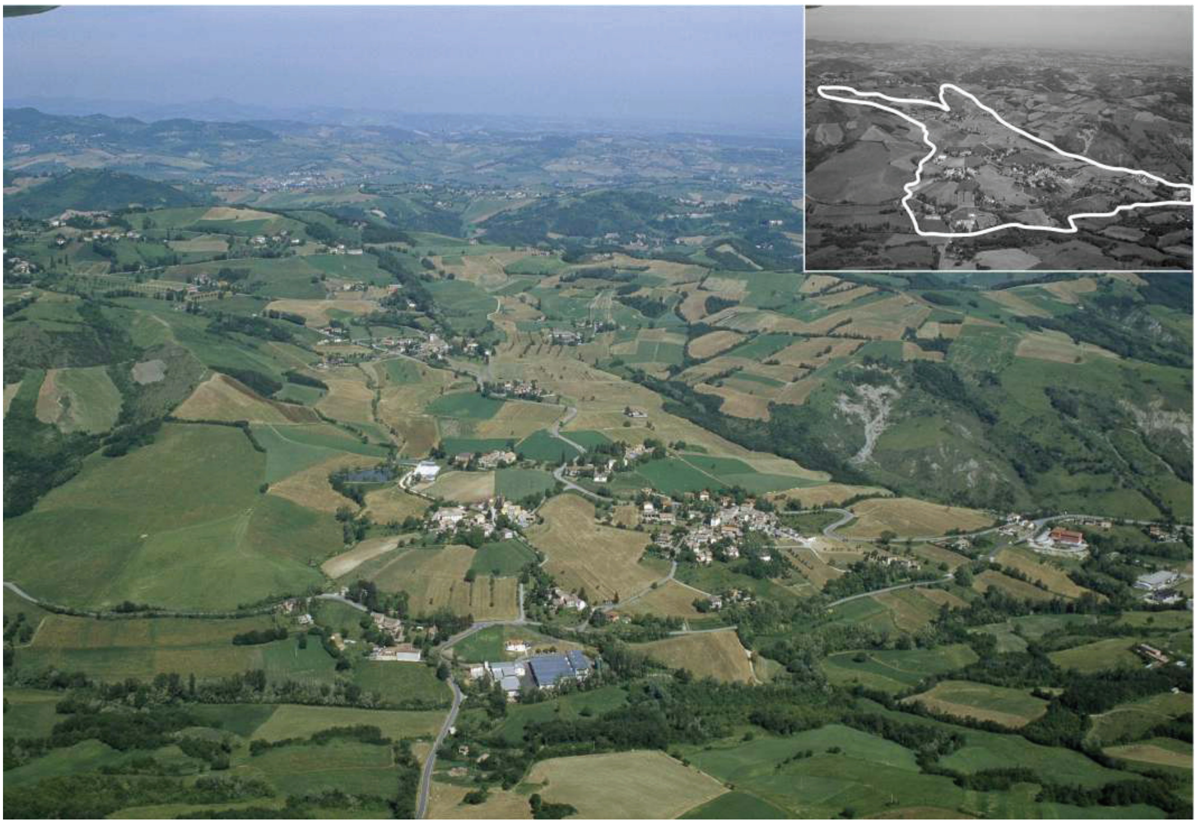

Figure 12. The Provazzano landslide in Province of Parma symbolises the problem of risk assessment and management in ancient, dormant earth flows. Five hamlets with several factories lie “undisturbed” on it. They have grown, during the last centuries and decades, almost only on the landslide that is the smoother area and *seems* the most reliable site of the versant. Photo by Bertolini G., 2006.

PRESENT RISK-REDUCTION STRATEGIES: TERRITORIAL FORECASTING

A new consciousness deriving from recent events

After the destructive reactivation of the Corniglio landslide (1994), archive research demonstrated that this landslide completely reactivated with similar behaviour also in 1559, 1612, 1740, 1770 and 1902. It is important to underline that the last reactivation occurred after almost a whole century of dormancy.

This event brought a new consciousness, causing a revolution in the regional legislation that became more restrictive and prudent.

In the subsequent ten years, further complete reactivations of ancient earth flows occurred (landslides of Casoletta, Cerrè Sologno, Magliatica, Boschi di Valoria, Cà di Sotto, Cà Lita, Morano; see also Figure 10). As a result, many others villages were damaged, relocated or required expensive consolidation work. These events led the regional authority to acknowledge that a detailed inventory of these large landslide bodies was the first step in order to reduce the risk.

The role of cartography, G.I.S. and territorial planning

The Emilia-Romagna Geological Survey was the first in Italy to carry out a complete geological map at the scale of 1 to 10.000. Afterwards, a Landslide Inventory Map (LIM) was derived. Landslides were classified on the basis of the observed state-of-activity and failure mechanism.

LIM became a powerful means of performing ***territorial forecasting*** and became a reference for urban management plans and several restrictions to build were imposed both on active and dormant landslides. On active ones all new constructions are forbidden. On dormant ones, new isolated constructions are forbidden and only existing hamlets and villages can extend, but only after detailed geological study and monitoring demonstrates that the risk is acceptable.

The law does not indicate how to assess the hazard related to dormant landslides. The decision is taken by local authorities (Provinces, *Comunità Montane*) through consultation between private consultants and geologists of the public administrations.

The basic criteria for a favourable decision depend on circumstances and are the subject of much debate, but to all intents and purposes can be summarised as follows:

- the hamlet or village must have existed for a long time without serious damage;
- the landslide must not show movements either at macroscopic or instrumental scale for an adequate period of time (one or more years);
- the foreseeable behaviour of the landslide in the event of reactivation (in terms of velocity and acceleration, estimated on the basis of analogous cases) must not pose a threat to human life;
- no records or memories of historical movements must exist;
- there must be no geomorphological agents acting on the landslide body or close to it (e.g. evidence of local instabilities or riverbank erosion in correspondence of the landslide toe);
- the inhabitants must be aware of the existing hazard.

FINAL REMARKS

The fifteen-year experience of risk management in Emilia-Romagna allows us to draw some consideration. Ancient landslide bodies are a factors of risk. Excessively prudent management of ancient landslide bodies might became also a “factor of risk”. The geological community has a responsibility: too many restrictions might inhibit human activity related to growth, even when local conditions might permit such activity (Figure 12). On the other hand, the previous situation of deregulation leads to extremely dangerous conditions.

Recent progress

During the last decade, great progress has been made:

- today we have clearly identified the position, shape, dimension and type of the region’s most dangerous landslide bodies;
- the great majority of these landslides are ancient earth flows built by superimposition of minor events over the last thousands of years;
- present-day landslide activity is nearly always related to the intrinsic instability of those ancient earth flows;
- above all, we have increasingly come to realize that the geological and recent history of large landslides is important in order to understand their present-day behaviour

Problems, methods and future goals: a brief conclusion

Active landslides are usually not problematic with regards to risk-management: if displacements are continuous or the landslide frequently resumes movement (for example every year or every few years) the population is aware of them. This is particularly true in the case of earth flows, which are very evident when active. In these cases, people easily accept rules and restrictions because they know that the hazard evidently exists. On the other hand,

defining and explaining the hazard related to more inactive earth flows deposits, those that have not moved for many years, decades or even centuries, is more difficult.
A deterministic approach including stability analyses and numerical modelling is useful in assessing triggering mechanisms (causes) but it has a limited forecast function in large, ancient earth flows situated in a complex geological context, as in many Apenninic slopes.

Inventory of landslides (e.g.: IFFI project, see Amanti et al, 2001) and in particular the historical research, has proved to be a very effective instrument for evaluating the hazard, but its quantitative significance in assessing the recurrence period is limited because of a series of factors such as the climate changes and the random loss of data.

Manual monitoring techniques (i.e. inclinometers) are very useful for measuring the dimensions and the state-of-activity of these landslides. On the other hand, this knowledge is useless for other purposes, such as the time-series analysis, because of the low frequency of the manual readings. This is particularly true for manual piezometers that may be misleading in the description of real water-table fluctuations.

Indeed, only continuous measures describe in which way the behaviour of the moving landslide is evolving (e.g.: acceleration or deceleration, pore pressure increasing or decreasing); in many cases they can also define the short-term risk (Bertolini 2005).

Among other risk-reduction strategies, the sharing of knowledge should not be overlooked. People accept restrictions and rules only if aware that the problem exists. Many initiatives aimed at the dissemination of maps and inventories are under way in Emilia-Romagna and, more generally, in Italy. Users can find information about the territorial distribution of landslides on various Internet sites, without restrictions (e.g.: www.regione.emilia-romagna.it/geologia /frane.htm and ww3.atlanteitaliano.it/atlante.htm).

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REFERENCES

AMANTI M, BERTOLINI G & RAMASCO M 2001. *The Italian landslides inventory –IFFI Project*. In Jorge E et al. (eds) Proceedings of III Panamerican Symposium on Landslides, Cartagena, Colombia, 29 July – 3 August 2001, Societad Colombiana de Geotecnica, Bogotà, vol 2, pp 841-846.

BASENGHI R & BERTOLINI G 2001. *Ricorrenza e caratteristiche delle frane riattivate durante in XX secolo nella Provincia di Reggio Emilia (Appennino Settentrionale).* Quad. Geol. Appl. **8**, Pitagora Ed, Bologna, Italy.

BAUM R L, SAVAGE W S & WASOWSKI J 2003. *Mechanics of earth flows*. Proceedings of the International Conference FLOWS 2003, Sorrento, Italy.

BERTOLINI G 2001. Modalità di riattivazione, interventi, caratteri geotecnica e mineralogici di una frana di argilla a struttura caotica (“Argille Scagliose” Auctt): la frana di Casoletta (Comune di Vezzano, Provincia di Reggio Emilia). Quad. Geol. Appl. 8, Pitagora Ed, Bologna.

BERTOLINI G, CANUTI P, CASAGLI N, DE NARDO MT, EGIDI D, MAINETTI M, PIGNONE R & PIZZIOLO M 2002. *Carta della Pericolosità Relativa da Frana della Regione Emilia-Romagna*. SystemCart, Rome, Italy.

BERTOLINI G & PELLEGRINI M 2001. *The landslides of the Emilia Apennines (northern Italy) with reference to those which resumed activity in the 1994-1999 period and required Civil Protection interventions*. Quad. Geol. Appl. **8**, Pitagora Ed, Bologna, Italy.

BERTOLINI G & TELLINI C 2001. *New radiocarbon dating for landslide occurrences in the Emilia Apennines (Northern Italy).* Trans. Japan. Geom. Un., **22** (4), C-23.

BERTOLINI G, DE NARDO MT, LARINI G & PIZZIOLO M 2004. *Landslides of the Emilia Apennines*. Field Trip Guide Book of the 32nd International Geological Congress, August 20-28, 2004, Florence (Italy). Edited by APAT, Rome, Italy.

BERTOLINI G 2005. *Monitoraggio di frane in area appenninica.* In: Proceeding of the Congress "Il monitoraggio e l'assetto idrogeologico: stato dell'arte e prospettive professionali (Milano, 9-10 ottobre 2003)", Ordine dei Geologi della Lombardia pp 125-136.

BERTOLINI G, GUIDA M & PIZZIOLO M. 2005. *Landslides in Emilia-Romagna region (Italy): strategies for hazard assessment and risk management*. Landslides **2**(4) pp 302-312, Springer-Verlag.

BERTOLINI G & PIZZIOLO M. 2006. *Le grandi frane dell'Emilia-Romagna: stato dell'arte*. In: Geologi, Ordine dei Geologi dell'Emilia-Romagna, Bologna, Italy.

BORGATTI L, CORSINI A, BARBIERI M, SARTINI G, TRUFFELLI G, CAPUTO G E PUGLIESI C 2005. *Large reactivated landslides in weak rock masses: a case study from the Northern Apennines (Italy).* Landslides, **3** (2) pp 115-124.

CALABRESI G & SCARPELLI G 1985. *Argille sovraconsolidate e fessurate: fenomeni franosi*. Geol. Appl. & Idrogeol., 20(2) pp 93-126. Bari, Italy.

CRUDEN DM & VARNES DJ 1996. *Landslide Types and Processes*. In: TURNER AK AND SHUSTER RL (eds), *Landslides: investigation and mitigation. Transportation Research Board, National Research Council*, Special Report 247, pp 36-75. National Academy Press, Washington DC, USA.

KO KO C, FLENTJE P & CHOWDHURY R 2004. *Interpretation of probability of landsliding triggered by rainfall*. Landslides 1 pp 263-275, Springer-Verlag.

LARINI G, MALAGUTI C, PELLEGRINI M & TELLINI C 2001. *"La Lama" di Corniglio (Appennino Parmense), riattivata negli anni 1994-1999*. Quad. Geol. Appl., **8**: 59-114, Pitagora Ed, Bologna, Italy.

LOLLINO G, BRUNAMONTE F, LARINI G & MALAGUTI C 2001. *La sperimentazione del Sistema Inclinometrico Automatizzato nel monitoraggio in continuo della frana di Corniglio (Parma) e ricerca di correlazioni significative fra le precipitazioni e la riattivazione del novembre 1994*. Quad. Geol. Appl., **8**: 59-114, Pitagora Ed, Bologna, Italy.

PIZZIOLO M 1996. *Carta Inventario del Dissesto*. Regione Emilia-Romagna, Bologna, Italy.

SKEMPTON A W 1964. *Long-term stability of clay slopes*. Geotechnique, 14-2, pp 75-101, London.

TELLINI C 2004. *Le grandi frane dell'Appennino Emiliano quali indicatori geomorfologici di variazioni climatiche*. Rassegna Frignanese, XXXIII, Accademia del Frignano "Lo Scoltenna" , Pievepelago, Modena, Italy.

WU T H, TANG W H, & EINSTEIN H H 1996. *Landslide hazard and risk assessment.* In: TURNER AK & SHUSTER RL (eds), Landslides: investigation and mitigation. Transportation Research Board, National Research Council, Special Report 247, pp 106-118. National Academy Press, Washington DC, USA.