

New data and interpretation of the huge clastic deposit of “La Pineda hill” (Vajont valley, northern Italy)

Carlo Esposito ^(a, b), Begoña Sánchez Cabanillas ^(a) & Francesca Bozzano ^(a, b, c)

^(a) Department of Earth Sciences, Sapienza University of Rome, Piazzale Aldo Moro, 5, 00185, Rome, Italy. E-mail: carlo.esposito@uniroma1.it

^(b) CERI Research Center of Sapienza University of Rome, c/o Department of Earth Sciences, Sapienza University of Rome, Piazzale Aldo Moro, 5, 00185, Rome, Italy.

^(c) NHAZCA S.r.l. Spin-off of Sapienza University of Rome, Via Cori, snc, 00177, Rome, Italy.

Document type: Short note

Manuscript history: received 28 December 2014; accepted 22 March 2015; editorial responsibility and handling by Gabriele Uras.

ABSTRACT

This paper focuses on a detailed study of the huge landslide deposit of “La Pineda” hill (Vajont Valley, northern Italy). The final aim is to define the geometric reconstruction of the landslide body and the transportation mechanism. This work is based on field investigations, data from a stratigraphic borehole and bibliographic data. As a result, we present a detail geological map of “La Pineda” hill and some cross sections that show the geometrical relationship between the landslide deposit and surrounding and underlying deposits. Finally, based on sedimentological, morphological and morphometric features of the deposit we conclude that the massive rock slope failure that produced La Pineda landslide evolved as a rock-avalanche.

KEY WORDS: Rock-avalanche, post-failure mechanism, “La Pineda” hill, Vajont valley.

INTRODUCTION

Large landslides are widespread in the contexts of high mountains in different geological-structural and morpho-climatic conditions.

These processes are an important morphogenetic factor in the evolution of mountain landscapes, in terms of both erosion and depositional rates (e.g. Fort et al., 2009; Hewitt et al., 2008). Furthermore, large landslides represent high magnitude events, especially if associated with high velocity of emplacement and large elongations, as in the case of rock-avalanches, which therefore represent potential factor of risk. In fact, rock avalanches originate from a massive flow of fragmented rocks that can move rapidly down a mountain slope; expanding and shattering mechanisms are responsible for large spreading and long run-out (Evans et al., 2006). Related deposits may be found several kilometres far from their detachment areas and debris may run up on the opposite slope (e.g. Bowman et al., 2012). In this context, understanding the dynamics of emplacement also of paleo-landslides can give an important contribution in understanding how the gravitational morphogenesis of some mountain areas realized and could therefore potentially develop in the future. This work is focused on “La Pineda” hill (fig. 1), located within the

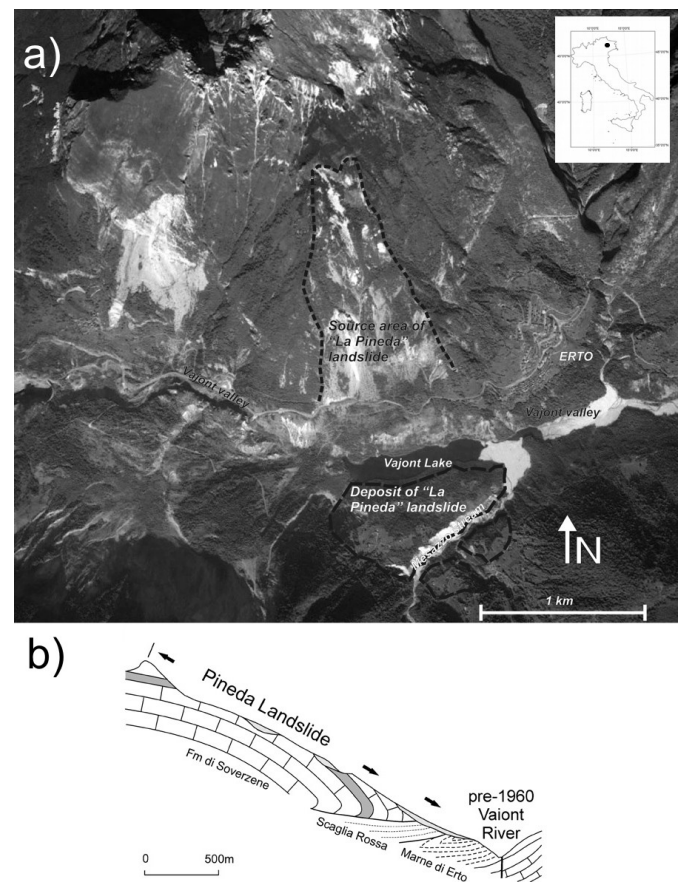


Fig. 1 – a) Satellite image (taken from Google Earth) of the study area; b) cross section along the source area (modified after Dykes et al., 2013).

Vajont Valley (Italian Alps). Such a hill is made up of debris generated by a large rock slope failure. The detailed study of this area is part of a monitoring project for the study of slope instability affecting the western slope of “La Pineda” hill. In particular, we present the results of an analysis, carried out mainly through accurate site surveys with the integration of

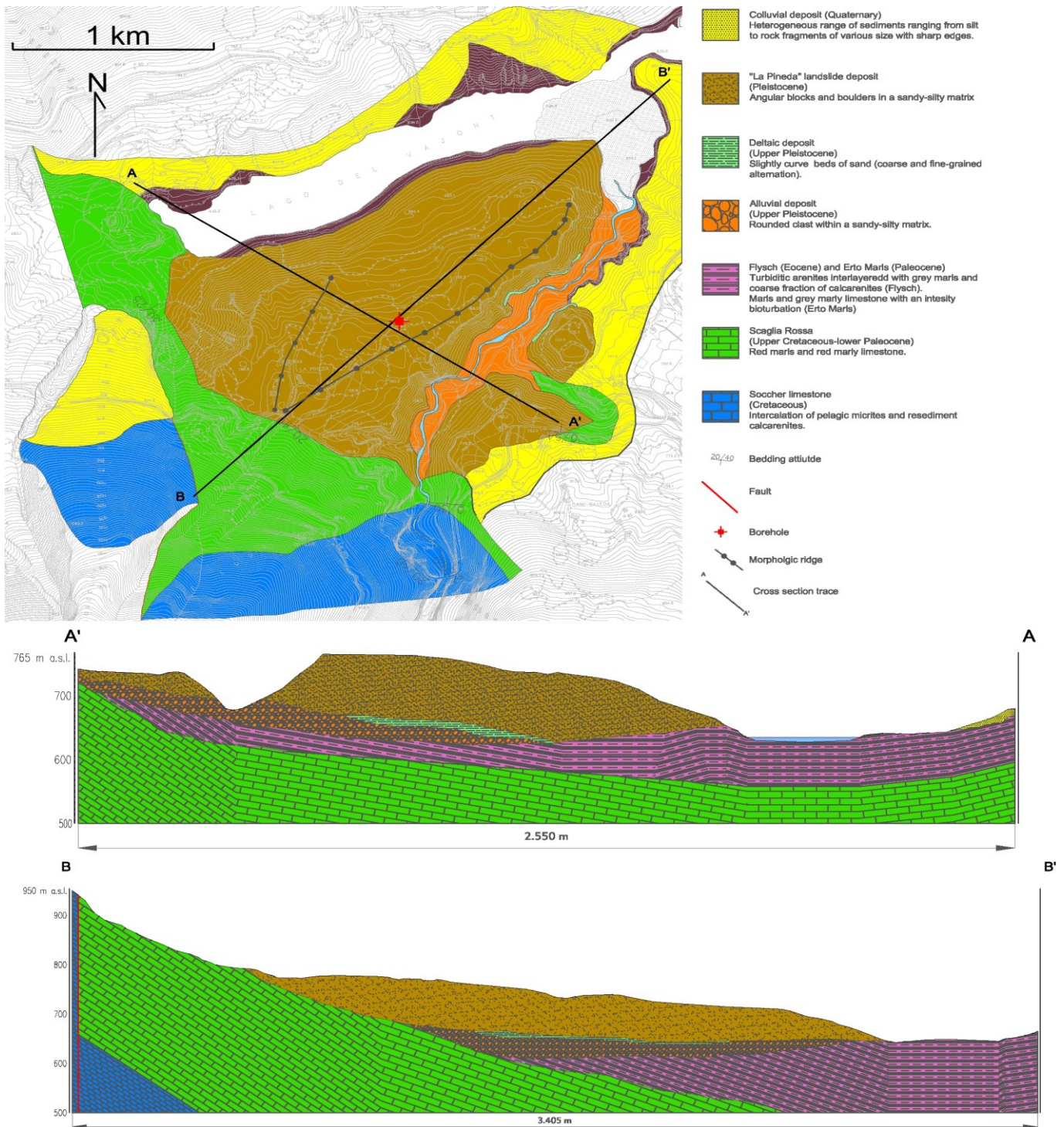


Fig. 2 – Geological map of “La Pineda” hill and related cross sections.

geognostic data, addressed to define in detail some features such as: i) the extension of the large debris deposit, attributable to the large paleo-landslide of “La Pineda”; ii) the volume of the deposit; iii) the main sedimentological and morphological features of the deposit in order to understand the post failure behaviour of “La Pineda” landslide.

GEOLOGY OF THE STUDY AREA

The section of the Vajont valley where “La Pineda” hill is located is mainly made up of a Jurassic-Paleocene marly-calcareous sequence (Soverzene Fm., Igne Fm, Vajont limestone, Fonzaso Fm, Rosso Ammonitico, Soccher

Limestone, Scaglia Rossa) deposited within the Belluno basin (Riva et al. 1990) and now largely outcropping on the mountain slopes. Following the arrival of the orogenesis-related compressive regime, the deposition environment gradually changed to a foredeep basin, which hosted the deposition of a thick sequence of marls and turbiditic arenites during Eocene (Erto marls and Flysch) (Riva et al. 1990). The local stratigraphic frame is completed by Quaternary, continental deposits of different origin, such as alluvial, glaciofluvial and lacustrine deposits and gravity-related clastic deposits.

The stratigraphic relationships among the different geological formations are strongly complicated by both faults and folds, also of regional importance. “La Pineda” hill is in fact located within in the core of a major fold structure: the Erto syncline with a WNW-ESE trending axis (Riva et al. 1990). The northern limb of the Erto syncline is reversed and stretched by Mt. Borgà thrust while the southern limb is characterized by a N-S sub vertical fault (col Tramontin fault).

Figure 2 schematically depicts the geological-structural frame of the study area and put in evidence the stratigraphic contacts of “La Pineda” landslide deposit with the surrounding and underlying geological units.

LA PINEDA DEPOSIT: SEDIMENTOLOGICAL AND MORPHOLOGIC FEATURES

“La Pineda” appears as a ridge separating the Vajont and Mesazzo valleys (fig. 3). Large outcrops along the river valleys clearly show a diamicton-like sedimentological setting of the hill. Such a chaotic debris has been already interpreted as the remnant of a paleo-landslide deposit. The source area has been identified on the right-hand slope of the Vajont valley, where the Soverzene Fm, Igne Fm., Vajont limestone and Scaglia Rossa crop out with a dip-slope attitude. A rock-slide mechanism along bedding planes has been inferred for this slope failure (Dykes et al., 2013) (fig. 1).

The landslide deposit is likely to have dammed the valley bottom; the so formed natural dam was subsequently eroded by the Mesazzo stream and Vajont river (Ghirotti et al., 2013), that deeply erode the debris.

As regards the dating no strong constraints can be found, except that the landslide deposit overlies on glaciofluvial delta deposits that entered (fig. 2) in a now extinct glacial lake (Ghirotti et al., 2013), thus suggesting that the landslide event occurred in a quite different morpho-climatic setting than the present one.

The sedimentological features of the landslide deposit are clearly visible along the flanks of Mesazzo stream and Vajont river that cut the hill, locally until the base.

The outcrops show the presence of angular rock clasts of different size (from blocks of some dm³ up to boulders of some tens of m³) interspersed in a sandy-silty matrix. The relative percentage of blocks, boulders and matrix is quite variable: the deposit appears somewhere matrix-supported and clast supported elsewhere.

As regards the internal organization of the deposit, it is possible to observe a general chaotic setting while sometimes a clear inverse sorting of blocks and boulders is recognizable. In addition, a concentration of huge boulders with few matrix is observable in the topmost part of the hill.

From the morphological point of view, the main feature is represented by the topography of the topmost part of the hill that has an average low gradient but where it is possible to observe two main ridges, parallel to each other and roughly SW-NE oriented.

The deposit has a volume of nearly 0.125 km³: it mostly overlaps alluvial and glaciofluvial delta deposit, while in the southern part overlaps Scaglia Rossa, as a result of the partial run-up on the opposite slope. (fig.4).

The above described sedimentological and morphological features strongly suggest a rock-avalanche mechanism of emplacement of “La Pineda” landslide.

The presence of a variable but significant proportion of sandy-silty matrix and fine graded (gravel) rock fragments can be considered the consequence of an intensive comminution of the original rock blocks that commonly occurs during a rock avalanche processes as a consequence of the fragmentation that takes place during the motion of such large rock masses (Hewitt et al., 2008; Davies and McSaveney, 2006).

The overall chaotic setting of the deposit together with the local evidence of inverse sorting of angular rock blocks and boulders are another common feature widely recognized in many other rock avalanche deposits: this setting is interpreted as the sedimentological reflection of the deposition of a granular flow, which is the typical transportation mechanism of a rock-avalanche (Hewitt et al., 2008).

The cap of coarse boulders, also referred to as “carapace”, is another distinctive element of rock avalanche deposits (Dunning and Armitage, 2010).

The presence of ridges quite perpendicular to the hypothesized direction of movement (fig. 2) can also be considered a clue for inferring a rock-avalanche dynamics, as these landforms can be the result of pressure waves occurring within the granular flows when an obstacle, such as the

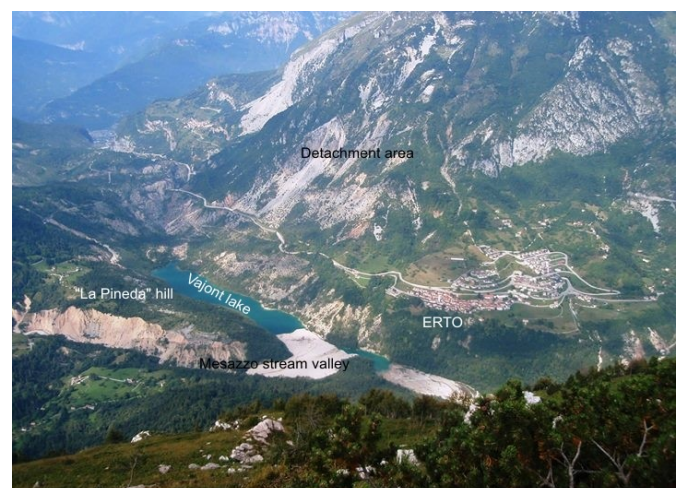


Fig. 3 – View of “La Pineda” hill (lower left part) from east.

opposite slope, causes an abrupt deceleration of the flowing mass (Hewitt, 2002).

Finally, the evidence of run-up on the opposite slope (cross section A-A' in figure 2) is indicative of a high mobility of the displaced rock mass, which is another distinctive feature of a rock-avalanche.

Other morphometric parameters confirm the hypothesis of a rock-avalanche dynamics. The long run-out ("L" of about 3150 m) and the vertical elevation difference ("H" of about 1075 m) allow us to estimate a fahrboschung angle of 18.8° . This value is typical of mass movements with high energy and high mobility that derive from an unusual physical behaviour, such as in the case of granular flows. If the estimated volume of the deposit of about 125.6 Mm^3 is also considered, it is possible to compare this landslide to other rock-avalanches all over the world by plotting the H/L vs V values on the plot by Finlay et al. (1999). The so obtained point falls within the cloud representing the rock-avalanches (fig. 4).

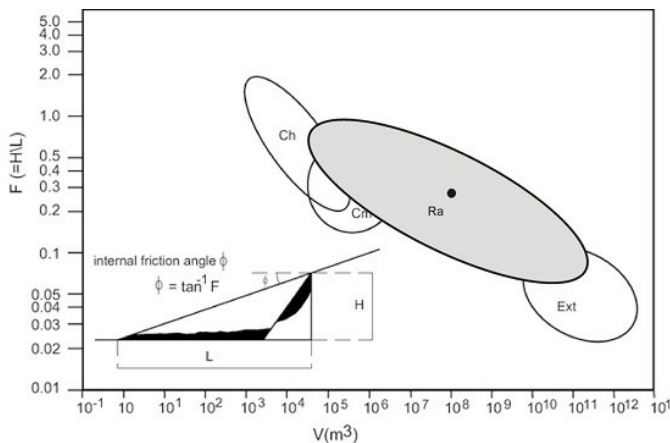


Fig. 4 – log f- log v diagram for various types of dry landslide. Grey ellipse indicates the field of rock avalanche (Ra) and the black circle the position of the “La Pineda” landslide. Ext: extraterrestrial landslide; Cm: coal mine waste rock; Ch: chalk. (modified after finlay et al., 1999).

CONCLUSIONS

As a result of the above described analyses, carried out by means of sedimentological and morphological/morphometric observation, we can conclude that taking into account the failure and post-failure behaviour, the massive rock slope failure that formed the deposit of “La Pineda hill” can be classified as a rock-slide-avalanche.

This result has implication in better defining and reconstructing the gravitational morphogenesis of the Vajont valley, that was characterized by large, catastrophic rock slope failures, sometimes accompanied by an unusual post-failure behaviour, i.e. rock-avalanche emplacement dynamics, able to magnify the already high landslide magnitude. Finally, due to the local extreme morpho-climatic conditions, monitoring

activities should be addressed to the identification of potential further rock slope failures occurring in other slope sections and/or as a development of the actual source area.

ACKNOWLEDGMENTS

We thank Adamo Filippin who provided the borehole stratigraphic data and we especially thank Gabriele Scarascia Mugnozza and Antonio Bratus for their help and advices during field investigations.

REFERENCES

- Bowman E.T., Take W.A., Rait K.L. & Hann C. (2012) - Physical models of rock avalanche spreading behavior with dynamic fragmentation. *Can. Geotech. J.* 49(4), 460-476.
- Dykes A.P., Bromhead E.N., Hosseini S.M. & Ibsen M. (2013) - A Geomorphological reconnaissance of structurally-controlled landslides in the Dolomites. *Italian Journal of Engineering Geology and Environment*, doi: 10.4408/IJEGE.2013-06.B-10.
- Dunning S. & Armitage P. (2010) - The grain-size distribution of rock-avalanche deposits: implications for natural dam stability. *Natural and Artificial Rockslide Dams*, 133. Springer, pp. 479-498. ISBN 978-3642047633.
- Evans S.G., Scarascia Mugnozza G., Strom A. & Hermanns R.L. (2006) - Landslide form massive rock slope failure and associated phenomena. Evans S.G., Scarascia Mugnozza G., Strom A.L. & Hermanns R.L. (Eds.). *Landslides from Massive Rock Slope Failure*. Nato Science Series Book, IV Earth and Environmental Sciences, 49. Springer, Dordrecht, The Netherlands, pp. 3-52.
- Finlay P.J., Mostyin G.R. & Fell R. (1999) - Landslide risk assessment: prediction of travel distance. *Can Geotech J.* 36(3): 556-562.
- Fort M., Cossart E., Deline P., Dzikowski M., Nicoud G., Ravel L., Schoeneich P. & Wassmer P. (2009) - Geomorphic impacts of large and rapid mass movements: a review. *Geomorphologie*, 1, 47-64.
- Ghirotti M., Masetti D., Massironi M., Oddone E., Sapigni M., Zampieri D. & Wolter A. (2013) - The 1963 Vajont Landslide (Northeast Alps, Italy) post-conference field trip (October 10th, 2013). *Italian Journal of Engineering Geology and Environment*, doi: 10.4408/IJEGE.2013-06.B-61.
- Hewitt K., Clague J.J. & Orwin J.F. (2008) - Legacies of catastrophic rock slope failures in mountain landscapes. *Earth-Science Reviews* 87: 1-38,
- Riva M., Besio M., Masetti D., Roccati F., Sapigni M. & Semenza E. (1990) - Geologia delle valli Vaiont e Gallina (Dolomiti orientali). *Annali dell'Università di Ferrara, sezione: Scienze della Terra*, 2(4):55-76.