



THE KNOWLEDGE OF THE VAJONT LANDSLIDE THROUGH THE PHOTOS OF EDOARDO SEMENZA: THE ENGLISH EXHIBITION

MONICA GHIROTTI^(*), DOMENICO CALCATERRA^(**) & FRANCESCO MARIA GUADAGNO^(***)

^(*)University of Ferrara - Department of Physics and Earth Sciences - Ferrara, Italy

^(**)Federico II University of Naples - Department of Earth, Environmental and Resources Sciences - Naples, Italy

^(***)University of Sannio - Department of Sciences and Technology - Benevento, Italy

Corresponding author: monica.ghirotti@unife.it

EXTENDED ABSTRACT

La “tragedia del Vajont” del 9 ottobre 1963, paradigma di una catastrofe di origine umana, è ripercorsa attraverso le eccezionali fotografie scattate dal Prof. Edoardo Semenza prima e subito dopo l’evento e presentata in una nuova mostra in lingua inglese. Edoardo Semenza era un geologo e uno dei principali ricercatori italiani in materia di frane. Ha lasciato un’impronta distintiva nella comprensione della struttura della Catena alpina, apportando contributi originali alla geologia, alla tettonica e alla geomorfologia delle Dolomiti. Semenza è stato il geologo che ha scoperto la presenza di un’antica frana sul versante settentrionale del Monte Toc, a monte della diga del Vajont, anni prima del manifestarsi di movimenti sul versante. Nelle fotografie dei tredici pannelli che compongono la mostra, diventano evidenti le intuizioni, la crescente consapevolezza e il senso di urgenza dell’uomo che per primo ha riconosciuto l’esistenza dell’antica frana. Rivelano il suo approccio “*mente et malleo*”, che gli consentì di elaborarne un modello e di definirne ciò che oggi chiamiamo scenari di rischio. La sua scoperta fu subito presa in considerazione dai responsabili dell’opera, almeno come ipotesi da verificare con altre ricerche ed indagini. Purtroppo, la sua consulenza, durata fino al 1961, non impedì che, dopo varie vicissitudini, si consumasse la tragedia. Le fotografie di Semenza ci permettono quindi di accedere sia alle sue dimensioni intime e personali, sia professionali.

La frana è ancora oggi oggetto di dibattito e riflessione scientifica, a causa dell’eccezionale quantità di dati disponibili, nonché del corpus di ricordi, storie e testimonianze che le comunità colpite conservano e continuano a costruire. Una parte di questi materiali, tratti dal volume e dal CD “Le foto della frana del Vajont” e dal libro di Edoardo Semenza sulla frana, è mostrata nei pannelli della mostra. Testi, immagini e didascalie sono selezionati e adattati da queste due pubblicazioni. La prima versione della mostra “*La storia del Vajont: la conoscenza della frana attraverso le foto di Edoardo Semenza*” è stata organizzata dall’Associazione Italiana di Geologia Applicata e Ambientale (AIGA) e dal Consiglio Nazionale dei Geologi (CNG) in occasione del cinquantesimo anniversario della frana. È stata inaugurata a Napoli durante il Congresso Nazionale dei Giovani Ricercatori in Geologia Applicata nel febbraio 2013 e ha proseguito il suo percorso in tutta Italia, ospitata da più di 30 sedi universitarie, vari licei, centri di ricerca e musei; entro la fine del 2014, è stata visitata da diverse migliaia di studenti. Attorno ad essa, i dipartimenti o i musei che l’hanno ospitata hanno organizzato numerosi eventi di natura divulgativa/scientifica, contribuendo in maniera significativa alla diffusione della cultura geologica per il rispetto e la protezione dell’ambiente. Nel 2023, una rinnovata versione della mostra, in inglese, è stata realizzata dall’AIGA e presentata al pubblico in occasione del 6° Forum Mondiale sulle Frane a Firenze, in coincidenza con il sessantesimo anniversario della tragedia del Vajont. Comprendere la natura e i suoi meccanismi evolutivi è l’obiettivo preminente di coloro che operano nell’ambito delle Scienze Geologiche applicate all’ambiente ed al territorio.

Ammirare le fotografie di Edo Semenza significa perciò accedere alla sua dimensione personale e professionale più intima. La frana è ancora oggi oggetto di dibattito e riflessione scientifica, anche per la straordinaria mole di dati disponibili, siano essi strumentali o tratti da rilevamenti. La mostra vuole perciò essere anche un invito al lettore a proseguire nelle ricerche, a partire da quelle di Edoardo Semenza e di altri studiosi che da allora hanno dedicato tanto del loro impegno allo studio della frana del Vajont.



ABSTRACT

The “Vajont disaster” of 9 October 1963, a paradigm of the catastrophe of human origin, is illustrated through the exceptional photos taken by Edoardo Semenza before and immediately after the event, presented in a new English exhibition. Edoardo Semenza was a geologist and one of the Italian leading landslide researchers. He put his distinctive mark on the understanding of the Alps, making original contributions to the geology, tectonics and geomorphology of the Dolomites.

Semenza was the geologist who discovered that an ancient landslide mass was present on the southern side of the Vajont valley upstream from the reservoir under construction, before the first movements occurred on the slope.

In the images shown in the thirteen roll-ups that make up the exhibition (Fig. 1), the intuitions, growing awareness, and sense of urgency of the man who first recognized the existence of the ancient landslide become evident. They reveal his “*mente et malleo*” (“with the mind and the hammer”) approach, which allowed him to develop a model of the slope and what today we call risk scenarios.

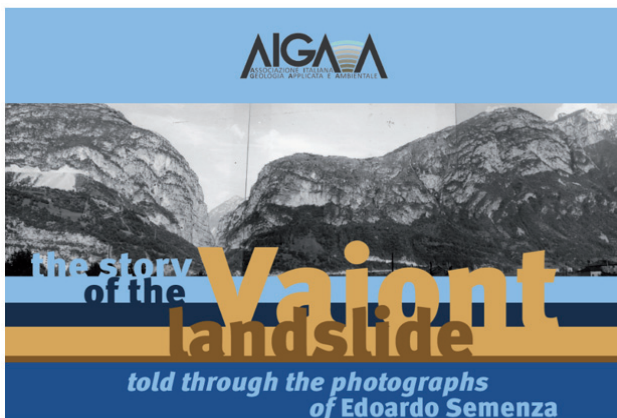


Fig. 1 - The title page of the exhibition

His discovery was immediately taken into consideration by the designer and project managers of the dam, albeit only as a hypothesis to be verified with follow-up research and investigations. Unfortunately, his work, which lasted until 1961, did not prevent the disaster from taking place.

The hundreds of photos of the landslide and of the valley taken by Semenza between 1959 and 1963, allow us to access both his intimate and personal, and professional dimensions.

A part of these materials, taken from the volume and CD “The photos of the Vajont landslide” and from Edoardo Semenza’s book on the landslide, is shown in the roll-up banners, and constitutes a contribution to the discussion. Texts, images and captions are selected and adapted from these two publications.

Through this exhibition and a renewed attention to Semenza’s work we hope to raise awareness on the fundamental role that the knowledge of geology holds for the

respect and protection of the environment.

The first version of the exhibition “*La storia del Vaiont: la conoscenza della frana attraverso le foto di Edoardo Semenza*” was organized by AIGA and the National Council of Geologists (CNG) on the occasion of the fiftieth anniversary of the landslide (GENEVOIS & PRESTININZI, 2013). It was hosted by over 30 university campuses, several high schools, research centers, and museums.

Launched in Naples during the National Conference of Young Researchers in Engineering Geology in February 2013, it continued its journey throughout Italy. By the end of 2014, it had been visited by several thousand students. Surrounding it, the departments or museums that hosted it organized significant events of a educational/scientific nature. It contributed to the spread of geological culture in general. It also received extensive coverage in national and local media and newspapers.

In 2023, a renewed graphical version of the exhibition, in English, was realized by the Italian Association of Engineering and Environmental Geology (AIGA - Associazione Italiana di Geologia Applicata e Ambientale) and presented to the public on the occasion of the 6th World Landslide Forum in Florence for the sixtieth anniversary of the Vajont disaster.

The landslide is still today the subject of debate and scientific reflection, due to the extraordinary amount of data available, as well as to the corpus of memories, stories, and testimonies that affected communities preserve and continue to build. Semenza repeatedly stressed the need to collect field data to understand slope failure conditions as a basis of correct landslide modelling. He strongly believed both in the role of geology and geomorphology as fundamental support to any engineering project and in the importance of a good communication between the various specialists working on large projects. In these aspects, just like in his research work, he was a pioneer and a leader for the whole geological community.

KEYWORDS: : Vajont Slide, Edoardo Semenza, exhibition.

THE 1963 VAJONT SLIDE

The Vajont landslide was a rock slope failure of 270 million m³ that occurred on October 9th, 1963 (Fig. 2a). It was triggered by the impoundment of a reservoir within the Vajont Valley, a tributary of the Piave River in northeastern Italy. The landslide, which had been slowly moving for several years before the failure at rates ranging from mm/day to cm/day, suddenly accelerated to a speed of about 100 km/hr. The landslide mass drove the water in the reservoir up to approximately 200 m up the north slope of the valley, forcing about 30 million m³ of water over the dam.

The resulting flood wave surged down the Vajont Valley to the Piave River, devastating numerous villages and most of the town of Longarone, resulting in over 1900 fatalities (SEMENZA & GHIROTTI, 2000).

The landslide occurred in a structurally complex setting (Fig. 2b), which strongly influenced both the morphology of the area and its long-term evolution (MASSIRONI *et alii*, 2013). In particular, the Erto syncline played a significant role in determining the location and direction of the Vajont Valley. The southern limb of the syncline, whose axis dips weakly eastward, forms the distinctive chair-shaped morphology of Mount Toc, visible from the Piave River valley and Longarone. Geological structures also controlled the boundaries of the landslide. The eastern boundary followed a sub-vertical scarp known as the Col Tramontin Fault, while the upper and part of the western boundaries followed the Col delle Erghene line. The Massalezza gully, located in the middle of the landslide, followed the axis of a north-plunging syncline, dividing the eastern and western limbs of the Vajont Slide (MASSIRONI *et alii*, 2013). The region's geology is characterized by the presence of

Triassic to Paleocene formations, namely: the Dolomia Principale Formation (Upper Triassic), the Soverzene and Igne Formations (Liassic), the Vajont Limestone (Dogger), the Ammonitico Rosso, Fonzaso, and Socchér Formations (Cretaceous-Jurassic), and the Scaglia Rossa Formation (Upper Cretaceous-Lower Paleocene) (Fig. 2c). The failure surface of the 1963 landslide followed mainly weak and thin clay layers, belonging to the Fonzaso Formation (HENDRON & PATTON, 1985).

Geological surveys, carried out by Edoardo Semenza and Franco Giudici on behalf of the dam owner company in 1959 and 1960 (GIUDICI & SEMENZA, 1960; SEMENZA, 1965; 2005; 2013), presented geological and geomorphological evidence indicating that a landslide occurred in the past on the southern slope of Mount Toc, filling the valley. This fill was subsequently eroded and carved by the Vajont Stream, leading to the morphology

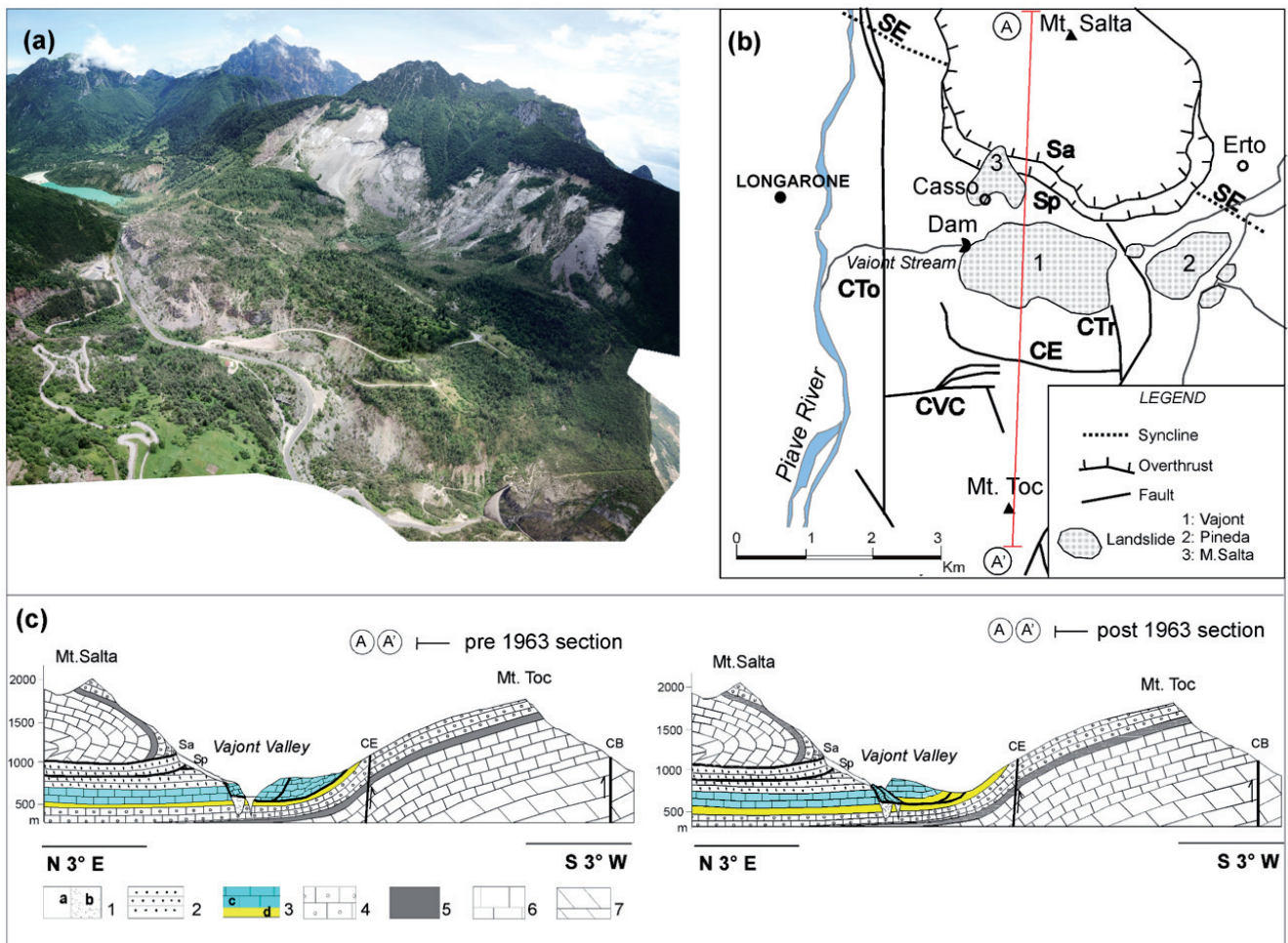


Fig. 2 - Overview of the landslide area. a) view of the scar and deposit of the Vajont Slide from the village of Casso, on the opposite side of the Vajont gorge; b) Tectonic map of the Vaiont area (modified from RIVA *et alii*, 1990); c) Geological sections before and after the 1963 landslide along the profile shown in insert (b). 1: Quaternary (a), Alluvial gravels (b); 2: Scaglia Rossa Fm.; 3: Socchér Limestone Fm. s.l. (c), Ammonitico Rosso and Fonzaso Fms.(d); 4: Vajont Limestone Fm.; 5: Igne Fm.; 6: Soverzene Fm.; 7: Dolomia Principale (modified from SEMENZA & GHIROTTI, 2000)

observed prior to 1963. However, the characteristics of such a prehistoric slope movement remain a topic of debate (e.g., MÜLLER, 1968; PARONUZZI & BOLLA, 2012; WOLTER *et alii*, 2016; DYKES & BROMHEAD, 2018).

The only information available regarding structural, geological, and geomorphological features of the Vajont Valley prior to the 1963 landslide is contained within several unpublished engineering reports (CALOI & SPADEA, 1960; GIUDICI & SEMENZA, 1960; MÜLLER, 1961) and overall into hundreds of photographs taken by Edoardo Semenza between 1959 and 1963 and collected in MASÈ *et alii* (2004). These photographs, in addition to being unique testimonies, are accompanied by descriptions and captions of extreme precision and detail.

These photographic images contain the geological and geomorphological evidence, no longer visible today, that led Edoardo Semenza to identify the existence of a paleo-landslide on Mount Toc and hypothesize its remobilization in the presence of the future reservoir, three years before the first movements occurred on the slope. In hindsight, they have formed the basis of numerous studies on the Vajont landslide and other major landslides.

The landslide is still today the subject of debate and scientific reflection, due to the extraordinary amount of data available, as well as to the corpus of memories, stories, and testimonies that affected communities preserve and continue to build. A part of these materials, taken from the volume and CD “The photos of the Vajont landslide” (MASÈ *et alii*, 2004 and SEMENZA, 2013), is shown in the roll-up banners, and constitutes a contribution to the discussion. Texts, images and captions are selected and adapted from these two publications. From them the intuitions, growing awareness, and sense of urgency of the man who first recognized the existence of the ancient landslide become evident.

Through this exhibition and a renewed attention to Semenza’s work we hope to raise awareness on the fundamental role that the knowledge of geology holds for the respect and protection of the environment.

The English version of the exhibition is translated and modified from “*La Storia del Vajont. La conoscenza della frana attraverso le foto di Edoardo Semenza*” (SEMENTZA, 2013) and edited by: Monica Ghirotti, Francesco M. Guadagno, Giovanni Masè, Michele Semenza, Paolo Semenza, Pietro Semenza and John J. Clague.

EDOARDO SEMENZA

Edoardo Semenza (1927-2002) (Fig. 3) was the engineering-geologist who recognized the existence of an ancient landslide on the southern side of the Vajont Valley, just upstream from the dam site still under construction.

The main geological and geomorphological evidences which led him to discover the ancient landslide and to define its shape, volume and limits and its possible consequent remobilization,

are illustrated through some of the photographs taken between 1959 and 1963. They help to understand both the geological complexity of the area and the peculiar structures of the valley, which contributed to hiding to previous and contemporary scholars the true nature of what they were analyzing and to hindering the recognition of related risks.

The identification of the ancient landslide was the result of a detailed geological survey and a great geological instinct. The Semenza’s work, carried out for many years afterwards, with passion and sacrifice, was internationally recognized only many years later (HENDRON & PATTON, 1985; SEMENZA & MELIDORO, 1992): we owe him the understanding of the geological foundations of this complex phenomenon, which have proven for any further investigation and verification.



Fig. 3 - Edoardo Semenza with the Vajont landslide in the background

Semenza spent more than 40 years of his academic career at Ferrara University as full professor in Engineering Geology: his geological insight, kindness and culture (he also wrote many poems, both in Italian and Latin) remain in the memory of colleagues, students and the whole Italian scientific community.

Semenza repeatedly stressed the need to collect field data to understand slope failure conditions as a basis of correct landslide modelling. He strongly believed both in the role of geology and geomorphology as fundamental support to any engineering project and in the importance of a good communication between the various specialists working on large projects. In these aspects, just like in his research work, he was a pioneer and a leader for the whole engineering-geological community.

THE EXHIBITION

The exhibition consists of thirteen roll-up panels illustrating, in chronological order, the phases of Semenza’s discovery. Some of these panels are reported in Figures 4 and 5.

NIGA The story of the Vaiont landslide told through the photographs of Edoardo Semenza

Evidence supporting the existence of the paleolandslide: Identification of the failure plane and the east margin of the landslide

10 - The bottom of the Vaiont Valley and the northeast edge of the paleolandslide
Photo: Edoardo Semenza, September 1959. Photo of the delta of the Vaiont. 05 - 10

The photographs in this panel provide the clearest evidence of the existence of the paleolandslide. They are the only ones that show position, thickness and eastern margin of the sliding plane mass.

Cataclases and tectonic breccias overlying intact bedrock were exposed in a small excavation through the talus accumulation shown in photograph 8 of panel 4 (photographs 10 and 11). The cataclases occurred in Fonzaso Limestone containing thin clayey interlayers, the same horizon associated with the catastrophic 1963 failure. Edoardo Semenza extended the cataclases within the Fonzaso Formation along the entire north wall and ascribed them to the failure of the paleolandslide. He furthermore recognized that the geological discontinuity between the east wall, where the subhorizontally layered landslide mass rested on cataclases, and the intact rock masses farther east marked a fault (the Col Tramontin fault). This boundary proved to be significant, as it marked the lateral right boundary of the 1963 landslide.

11 - The excavation that exposed the failure surface
Photo: Edoardo Semenza, September 1959. Photo of the delta of the Vaiont. 05 - 11

The excavation next to the small path visible in photograph 8 exposed cataclases that separated the paleolandslide (in the upper right) from fractured bedrock (lower left).

Also evident is the strong discordance between the several folded layers of the ancient landslide at the right and rock layers to the left of and below the gully that dip steeply towards the northeast. The cataclases visible in photograph 11 was found during an excavation along the small (top) just below the upper wall. Note also the talus and, beneath it, the bedrock layers.

The north wall (photographs 8 and 9 of panel 4 and photograph 10 of panel 5) bordered the so-called eastern wall, which Edoardo Semenza described in this manner: "Along the eastern wall of the paleolandslide the structure was dominated [...] steep cavities [...] heavily fractured and [...] vertical cracks". A funnel-shaped gully filled with debris is visible at the centre of the photograph.

At the top, the building yard (left), the new road and a bedrock wall; at the bottom the old road; in the middle left an abandoned road. Note the contrast between the rocky wall (overhangs the new road (currently a practice wall for climbing) and slopes downward to the right and left, and the rock masses (1 and 7) that rise between the two roads. In the central part of the photo, bedrock to the rocky wall dips repeatedly towards the right (east), whereas the central rock masses are heavily fractured, with variable dip. The rock mass at the right (1) has an loose sediment; after 1963 it was named "colle isolato" (see text and more photographs of Colle Isolato in the following two panels).

12 - North side of the Vaiont Valley just upstream of the Colomber Bridge
Photo: Edoardo Semenza and Giuseppe Cusi, 1959. Photo of the delta of the Vaiont. 05 - 12

The hammer at the lower right provides a sense of scale - the cataclases at this place are about 1 meter thick.

13 - Sliding surface of the paleolandslide
Photo: La Mura del Vaiont, June 59.

1959 hypothesis

August 1960

Two north-south profiles through Pian della Pozza. "S" indicates the sliding surface of the paleolandslide.

The sliding surface (A) proposed by Edoardo Semenza in the summer of 1959 (see Skidell and Semenza, 1960) and (B) formulated after the geological survey carried out in the summer of 1960.

There is no rock outcrop just below the level of the church on the north side of the valley; instead, one can see great in a cut that corresponds to the old channel of the Vaiont Stream before the paleolandslide. Similar arrangements of the gorge occurred 100 m upstream, at the hotel on the right side of the photograph and at Colle Isolato (photograph 14).

14 - The narrow Vaiont gorge at Colomber Bridge, from the walkway downstream from the dam
Photo: Edoardo Semenza, September 1959. Photo of the delta of the Vaiont. 05 - 14

Layout of the valley before the ancient landslide.

Ancient landslide filling the valley.

Incision of the new channel of the Vaiont Stream south of the old stream channel (as seen in a north-south section passing through Colle Isolato. In the northeastern part of Colle Isolato, the rock layers were visibly folded, their attitudes changed in a northerly direction from sub-horizontally to sub-vertical or even overturned. This folding gave Semenza the idea that the Colle Isolato rock mass was part of a landslide that involved the north west of the valley from the south.

In 1964, during excavation of the bypass gallery, Vaiont Stream deposits were encountered at the base of Colle Isolato. After the ancient landslide, the Vaiont Stream cut a new channel into the landslide mass and the underlying bedrock, including a portion of the foot of the landslide. From the south side of the valley, the discovery of these alluvial deposits confirmed the Semenza's hypothesis, formulated in 1959, of mass Colle Isolato toward.

Section III', from Semenza and Ghivetti (2006), illustrates what was found clearly one after the first dissection of the reservoir in February 1963. Colle Isolato (indicated by the arrow) covers the paleo-streambed filled with alluvial deposits.

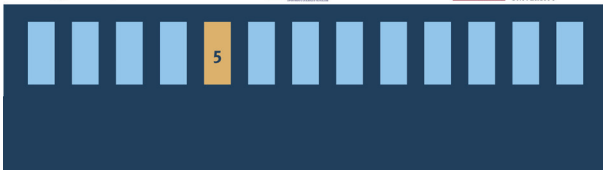


Fig. 4 - Panel 5: Evidence supporting the existence of the paleolandslide: identification of the failure plane and the east margin of the landslide

NIGA The story of the Vaiont landslide told through the photographs of Edoardo Semenza

New conclusions on the existence of the paleolandslide: Summer of 1960

Upon receiving Edoardo Semenza's communication, Engineer Carlo Semenza decided to perform further investigations to verify the existence of the paleolandslide and its thickness. The additional investigations included geophysical surveys, topographic monitoring of the slope and the drilling of three holes between Pian del Loc and Pian della Pozza. However, the drillers encountered rock so intensely fractured that progress was extremely difficult, and at some depth, the drillholes had to be abandoned before reaching intact bedrock (Vaiont Limestone).

From the drilling data, Edoardo Semenza deduced that the paleolandslide was thicker than that he had estimated in 1959 and furthermore that the ancient failure plane could not outcrop near the Pian della Pozza depression, but rather farther uphill. He therefore concluded that the landslide mass must have been much larger than 50 million cubic meters, his previous estimate.

A geologic survey was conducted farther upslope in the summer of 1960 (see photograph 21, panel 9). Discovery of the upper margin of the paleolandslide led Edoardo Semenza to the following conclusions (The Story of Vaiont p. 97):

"The mass in question, limited at the base by a thick level of cataclases and mylonites (more or less heavily fractured or even ground up rock) was made up, in the remainder, of rock that was somewhat less fractured. In the upper part, the mass rested on solid rocky strata dipping north at 40°.

The upper margin of the mass reached approximately the little depression of the elevation of 1130 m to the west of Massolezza Stream, and it must have been very high to the east as well."

Based on the new geological information, Semenza drew a series of geological sections that showed the probable location and shape of the paleolandslide failure surface. He argued that a mass of approximately 200 million cubic meters might fall along this plane.

15 - A sketch drawn by Edoardo Semenza in his field-notebook
Photo: Edoardo Semenza, September 1959. Photo of the delta of the Vaiont. 05 - 15

16 - The narrow Vaiont gorge at Colomber Bridge, from the walkway downstream from the dam
Photo: Edoardo Semenza, September 1959. Photo of the delta of the Vaiont. 05 - 16



Fig. 5 - Panel 7: New conclusions on the existence of the paleolandslide: summer of 1960

The last panel of the exhibition presents Edoardo Semenza's final scientific contribution to the Vajont landslide: a palinspastic reconstruction of the paleo-landslide zone (Fig. 6), it shows the successive movements of the slope over time, from early post-glacial time (?) (profile 1) to the last stage in 1963 (profile 8).

The entire exhibition, in both Italian and English versions, can be viewed on the AIGA website (<https://www.aigaa.org/>).

The authors wish, at the end of this note, to commemorate the figure of Edoardo Semenza through the words of Alfred J. Hendron Jr. and Franklin D. Patton, taken from the preface of the book "The Story of Vajont Told by the Geologist Who Discovered the Landslide" (SEMENZA, 2010): "In some ways the story of Vajont can be compared to a Greek tragedy. The project engineer, Carlo Semenza, was told at various times by one or more of his experienced consultants Dal Piaz, Caloi, Penta, Müller, and others that it was unlikely: 1) there was a significant previous landslide, 2) the moving rock could be stabilized by drainage, and 3) further movements of the slide would be fatal to the project. On the other hand, his son Edoardo, a recent geology graduate, was telling him: 1) there was a very large pre-existing slide deposit located just upstream from the dam, 2) the slide had previously moved across the valley, 3) the slide was resting on weak materials and 4) the old slide could be reactivated by the rising reservoir. As we now know, Edoardo was correct. We think that these conflicting technical opinions provided the real drama prior to the slide, not the contrived plots of the reporters and the authors of the play and the movie."

ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to the Semenza Family for the generous contribution in making their father's research legacy available to the Italian and international scientific community.

REFERENCES

- CALOI P. & SPADEA M.C. (1960) - *Serie di Esperienze Geosismiche Eseguite in Sponda Sinistra a Monte della Diga del Vajont (Dicembre 1959)*. Unpublished technical report for Società Adriatica di Elettricità, Venice, Italy (in Italian).
- DYKES A.P. & BROMHEAD E.N. (2018) - *The Vaiont landslide: re-assessment of the evidence leads to rejection of the consensus*. *Landslides*, **15**: 1815-1832.
- GENEVOIS R. & PRESTININZI A. (EDS.) (2013) - *Internazionale Conference on Vajont – 1963-2013. Thoughts and analyses after 50 years since the catastrophic landslide*. *Italian Journal of Engineering Geology and Environment - Book Series*, **6**: 631 pp.
- GHIROTTI M. (2012) - *The Vaiont Slide*. In: CLAGUE J. J. & STEAD D. (EDS.) - *Landslides: Types, Mechanics and Modeling*. Cambridge University Press: 359-372.
- GIUDICI F. & SEMENZA E. (1960) - *Studio geologico sul serbatoio del Vajont*. Unpublished technical report for Società Adriatica di Elettricità, Venice, Italy (in Italian).
- HENDRON A.J. & PATTON F.D. (1985) - *The Vaiont Slide: A Geotechnical Analysis Based on New Geologic Observations of the Failure Surface*. US Army Corps of Engineers Waterways Experiment Station, Technical Report GL-85-5.
- MASÈ G., SEMENZA M., SEMENZA PA., SEMENZA P. & TURRINI M.C. (2004) - *Le Foto della Frana del Vajont*. K-flash Ed., Ferrara. CD-ROM (in Italian).
- MASSIRONI M., ZAMPIERI D., SUPERCHI L., BISTACCHI A., RAVAGNAN R., BERGAMO A., GHIROTTI M. & GENEVOIS R. (2013) - *Geological structures of the Vajont Landslide*. *Italian Journal of Engineering Geology and Environment*: 573-582. <https://doi.org/10.4408/IJEGE.2013-06.B-55>
- MÜLLER L. (1961) - *Talsperre Vaiont: 15° Baugeologischer Bericht - Die Felsgleitung im Bereich Toc*. Unpublished technical report for Società Adriatica di Elettricità, Venice, Italy (in German).
- MÜLLER L. (1968) - *New Considerations on the Vajont Slide*. *Rock Mech. Eng. Geol.*, **6**(1-2): 1-91.

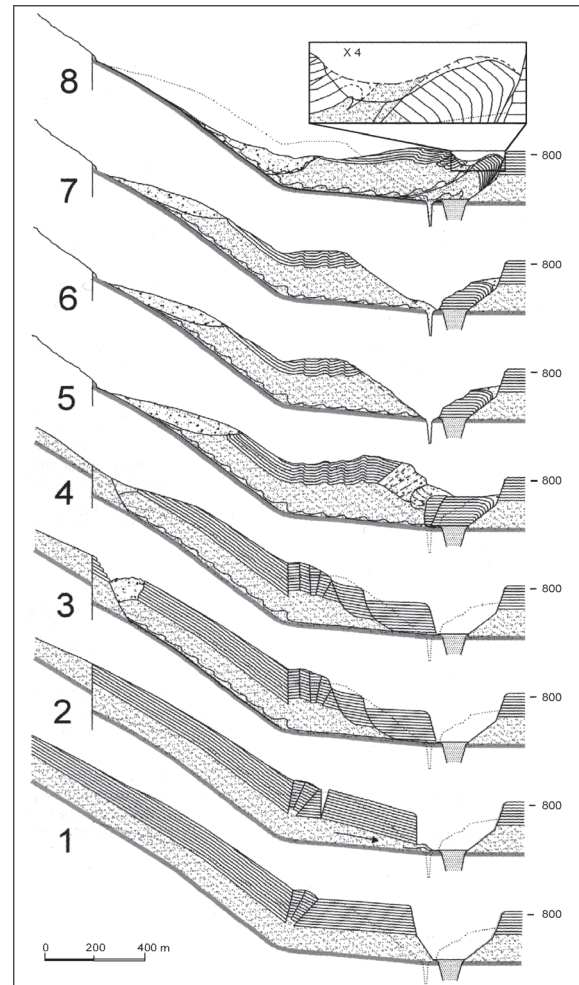


Fig. 6 - Palinspastic reconstruction of the Vajont landslide, beginning with (1), the early post-glacial mass movement, and ending with (8), the 1963 landslide (SEMENZA, 2010)

- PARONUZZI P. & BOLLA A. (2012) - *The prehistoric Vajont rockslide: an updated geological model*. *Geomorphology*, **169–170**: 165-191.
- RIVA M., BESIO M., MASETTI D., ROCCATI F., SAPIGNI M. & SEMENZA E. (1990) - *La geologia delle valli Vaiont e Gallina (Dolomiti orientali)*. *Annali dell'Università di Ferrara, Sezione Scienze della Terra*, **2**(4): 55-76 (in Italian).
- SEMENZA E. (1965) - *Sintesi degli studi geologici sulla frana del Vaiont dal 1959 al 1964*. *Memorie del Museo Tridentino di Scienze Naturali*, **16**(1): 1-52.
- SEMENZA E. (2010) - *The Story of Vaiont told by the Geologist who Discovered the Landslide*. Published posthumously. Ferrara: K-flash [available at www.k-fl.ash.it].
- SEMENZA E. (2013) - *La Storia del Vaiont raccontata dal geologo che ha scoperto la frana*. Published posthumously. Ferrara: K-flash [available at www.k-fl.ash.it] (in Italian).
- SEMENZA E. & GHIROTTI M. (2000) - *History of the 1963 Vaiont Slide: the importance of geological factors*. *Bulletin of Engineering Geology and the Environment*, **59**(2): 87-97.
- SEMENZA E. & MELIDORO G. (ED.). (1992) - *Proceedings of the Meeting on the 1963 Vaiont Landslide, 1*. International Association for Engineering Geology and the Environment, Italian Section, University of Ferrara, Ferrara, Italy, 1986.
- WOLTER A., STEAD D., WARD B.C., CLAGUE J.J. & GHIROTTI M. (2016) - *Engineering geomorphological characterisation of the Vajont Slide, Italy, and a new interpretation of the chronology and evolution of the landslide*. *Landslides*, **13**(5): 1067-1081.

Received February 2024 - Accepted April 2024