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Application of ERT to landslide investigation using innovative systems: FullWaver and MultiSource in the Alps

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Abstract

This study demonstrates the effectiveness of applying Electrical Resistivity Tomography (ERT) to investigate the internal structure of an active alpine landslide. The use of two innovative systems - MultiSource and FullWaver - allowed for the acquisition of high-density 2D and 3D resistivity datasets, achieving investigation depths greater than 200 meters. The results revealed a well-defined conductive zone interpreted as a saturated, mechanically weak pelitic-marly complex, bounded by resistive carbonate formations. The 3D resistivity model confirmed the presence of a bowl-shaped sliding structure underlying the inhabited area of Cazzaso. These findings contribute significantly to the understanding of the geoelectrical and hydrogeological behavior of deep-seated landslides and provide a solid basis for future monitoring and mitigation strategies. The application of such advanced distributed ERT systems opens new possibilities for landslide characterization and risk management in complex geological settings.

Introduction

The geophysical characterization of unstable areas, such as landslide zones, is essential for geological risk assessment and for the development of mitigation strategies. Among the available techniques, Electrical Resistivity Tomography (ERT) has emerged as a powerful tool for indirect subsurface investigation. This study presents the results of geophysical surveys conducted in the Cazzaso landslide area, located in the municipality of Tolmezzo (UD), in the Alpine region of northern Italy. The main objective was to characterize the landslide body using innovative geophysical methods, with a focus on ERT. The Cazzaso landslide is located on the eastern slope of Mount Diverdalce, within the Fusea - Cazzaso - Sezza plateau area. It has shown multiple reactivation events over time. The morphology is typical of a deep-seated landslide: the upper sector is steep and rugged, while the lower part, where the village of Cazzaso is situated, is more gently sloped and terraced. The landslide affects a complex geological setting that includes pelitic-marly-arenaceous formations, dolomites, and stratified carbonates of Carnic age. These materials present sharp resistivity contrasts and heterogeneous hydrogeological behavior, which make the site ideal for ERT investigation. Understanding the structure and dynamics of this landslide is critical, as it affects both natural slopes and inhabited areas.

In recent years, the use of electrical resistivity methods for deep subsurface exploration has grown significantly. This trend has brought important developments to the field of applied geophysics, enabling the acquisition of large datasets under diverse geological conditions (Lajaunie et al., 2019; Rizzo et al., 2020; Bocchia et al., 2021). The advancement of DERT techniques has fostered the development of multichannel and distributed systems based on loggers capable of continuously sampling electrical potentials through multiple electrode pairs inserted into the ground. In parallel, ERT monitoring has become an effective tool for studying variations in moisture content and subsurface water flow in landslide areas, aquifers, levees, and other geotechnical systems. New-generation resistivity meters, such as the FullWaver (Gance et al., 2018) and the Multisource system (LaBrecque et al., 2013; Bocchia et al., 2021), allow for high-frequency, high-quality data acquisition, enhancing the temporal and spatial resolution of the resulting models.

In this context, the application of DERT in the Cazzaso area aimed to map the geometry of the landslide body, identify structural weaknesses, and provide valuable data to support future monitoring and stabilization efforts. The results highlight the potential of deep resistivity imaging for understanding complex geodynamic processes in Alpine environments.

Method

The geophysical survey was conducted using two new-generation electrical resistivity systems: the MultiSource system (MPT-IRIS Inc.) and the FullWaver system (IRIS Instruments). Both are distributed acquisition platforms capable of high-density and high-resolution data collection over large areas and depths, designed to overcome many limitations of traditional wired ERT arrays. The survey design included five 2D ERT profiles and a 3D volumetric acquisition, covering the most critical sectors of the landslide (Figure 1). The 2D lines were acquired with the MultiSource system using 16 wireless transceiver units, totaling 48 electrodes deployed per profile. The acquisition geometry was primarily dipole–dipole, with configurations involving single current injection (1TX) and simultaneous current injections (2TX, and 4TX) to increase the depth of investigation and signal-to-noise ratio. A preliminary test survey (ERT1) was conducted to assess site-specific electrical response, followed by longer profiles aligned both longitudinally and transversely to the landslide body.

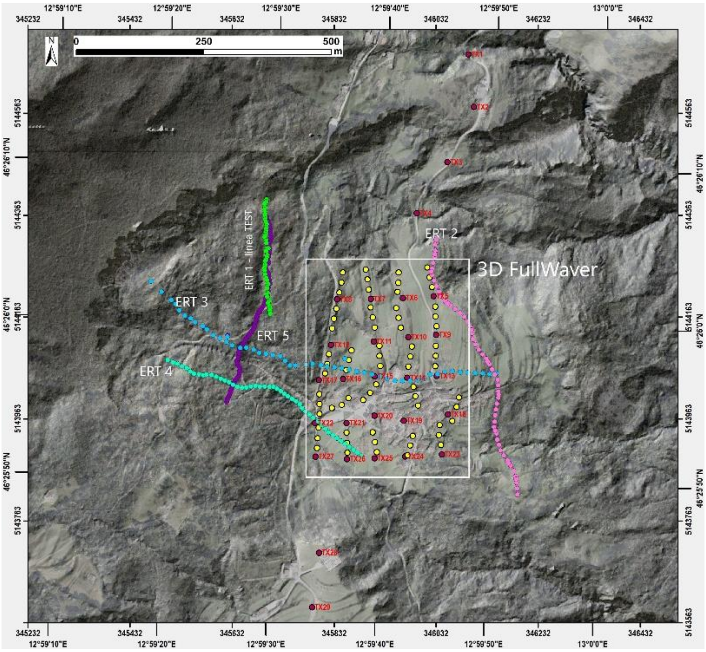

Figure 1: *Layout of 2D ERT survey lines and 3D FullWaver acquisition grid over the landslide area.*

The 3D survey was performed on the lower, inhabited sector of the landslide using the FullWaver system, which consists of a high-power current transmitter (TIPIX 3000, up to 13 A) and 27 autonomous receiving units (V-FW) equipped with GPS for synchronization. A total of 58 current injections were executed using two configurations: forward mode (fixed pole at TX1, moving pole from TX2-TX29) and reverse mode (fixed pole at TX29). These configurations allowed the acquisition of dipole-dipole, pole-dipole, and gradient arrays, covering a maximum aperture of 1100 meters and reaching investigation depths of over 200 meters.
All positioning was carried out using a Leica Viva GS14 GNSS system in RTK mode, ensuring sub-decimetric accuracy for georeferencing the electrode locations. Data acquisition was complemented by detailed topographic surveying and the application of modeling tools to pre-assess the sensitivity and depth of investigation (DOI) for each planned configuration. Data processing was conducted with ERTLab Studio (Geostudi Astier), adapted to handle both

MultiSource and FullWaver datasets. The 2D and 3D datasets were processed independently and later integrated to build a continuous and robust subsurface resistivity model. Inversion was performed using the Occam regularization approach, with typical convergence reached within 6 - 8 iterations and a good match between measured and modeled datasets.

Results and Interpretation

The integration of 2D ERT profiles and the 3D FullWaver survey provided a high-resolution image of the subsurface structure of the Cazzaso landslide. The resistivity models revealed a complex litho-structural framework, with strong contrasts between conductive and resistive geological units, which are critical for understanding the landslide dynamics. In all sections, a thick conductive body was clearly identified, extending in depth and laterally across the landslide body. This low-resistivity zone (30 - 100 Ω·m) corresponds to a pelitic-marly-arenaceous complex, interpreted as saturated, fine-grained materials that act as a mechanically weak layer (Figure 2). These materials are confined between more resistive units, primarily dolomites and stratified carbonates (>250 Ω·m), which dip towards the northeast and may serve as sliding surfaces or lateral limits to the landslide.

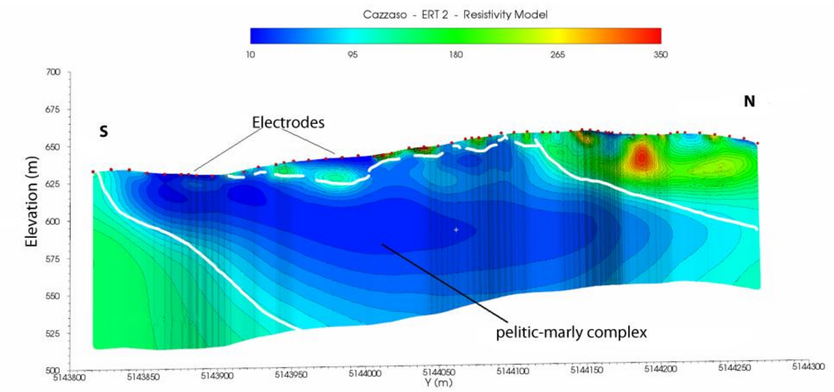

Figure 2: *2D Electrical Resistivity Tomography (ERT) section across the landslide body highlighting the conductive pelitic complex.*

The 3D FullWaver volume highlighted the continuity and geometry of this conductive zone, showing a bowl-shaped structure beneath the inhabited sector of Cazzaso (Figure 3). The highest resistivity values, exceeding 400 Ω·m, were associated with compact carbonate rocks, particularly in the southern and deeper portions of the model. In contrast, zones of low to intermediate resistivity in the upper part of the model indicate weathered and potentially saturated materials affected by infiltration processes.

Time-lapse observations and pseudo-section analysis suggest that the internal structure of the landslide is highly heterogeneous, with potential preferential pathways for water flow, especially along the interfaces between resistive and conductive layers. This behavior was also confirmed by complementary spontaneous potential (SP) measurements and visual correlation with terraced morphologies in the field. Overall, the results demonstrate the effectiveness of the ERT approach in resolving the internal architecture of complex alpine landslides, providing valuable information on potential failure surfaces, lithological contacts, and zones of elevated hydrogeological activity.

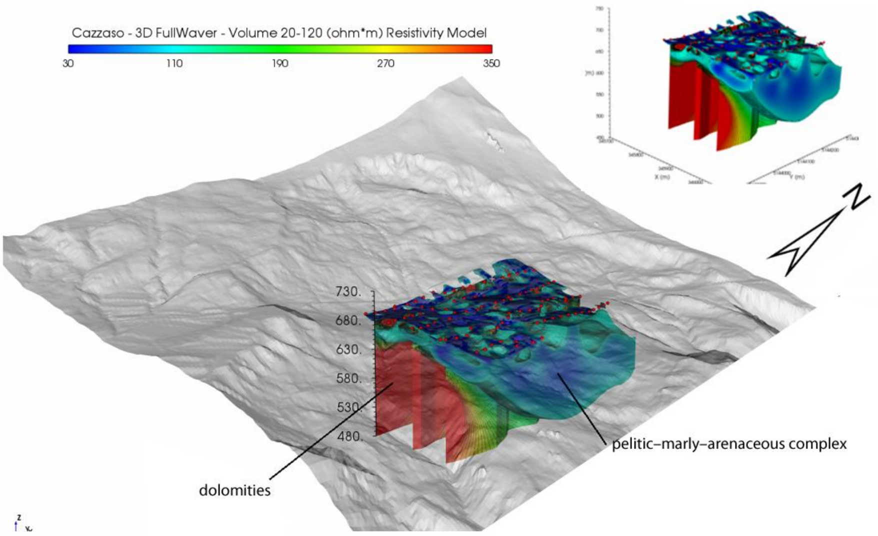

Figure 3 *- 3D Resistivity model from the FullWaver survey showing the geometry of the conductive Pelitic - Marly - Arenaceous complex.*

Conclusions

The application of innovative electrical resistivity tomography techniques using MultiSource and FullWaver systems allowed for a detailed geophysical characterization of the Cazzaso landslide. The combination of 2D and 3D ERT data enabled the reconstruction of the internal geometry of the landslide body, revealing a thick conductive pelitic-marly-arenaceous complex confined between more resistive dolomitic and carbonate formations. The results confirmed the presence of a bowl-shaped, low-resistivity zone beneath the inhabited area of Cazzaso, interpreted as the main sliding body. The high-resolution imaging achieved at depths exceeding 100 meters demonstrates the effectiveness of distributed acquisition systems in resolving deep-seated geological structures.This case study highlights the potential of advanced ERT systems for landslide analysis in complex geological settings and suggests their applicability in similar risk-prone areas. The methodology provides a robust foundation for long-term monitoring strategies and for guiding future geotechnical interventions.

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