APPLICATION OF ELECTRICAL RESISTIVITY TOMOGRAPHIES FOR THE GEOELECTRIC CHARACTERIZATION OF MONTAGUTO LANDSLIDE (SOUTHERN ITALY)

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Introduction. This paper reports the results of a geoelectrical survey carried out on the Montaguto landslide, located in the Apennine Chain (Campania Region, Southern Italy) (Fig. 1).

Montaguto landslide is an earthflow and it is considered one of the larger and complex mass movements in Europe, with a length of about 3 x 10^3 m, an estimated volume of displaced material of about 4-6 x 10^6 m³ and a sliding surface depth varying from 5 m, near the center, to 20-30 m, at the toe. Its areal extension is about 6.6 x 10^5 m² (~66 ha), whereas its width ranges between 45 and 420 m (Ventura et al., 2011; Giordan et al., 2013; Guerriero et al., 2013). As stated by Ventura et al., (2011), the depth of the water table roughly corresponds to the thickness of sliding material with sag ponds occurring in the upper and central zone. The altitude gap between the head scarp, 830 m a.s.l., and the toe, 420 a.s.l., is about 420 m (Giordan et al., 2013).

The earth-flow has been active for almost 60 years starting from, at least, 1954. Long periods of relatively slow movement and shorter periods of relatively rapid movement periodically follow one another in the earth-flow activity (Guerriero et al., 2013).

In the mid spring season 2006 began the most extensive reported slope failure, when an estimated volume of 6 x 10^6 m³ earthflow activated. Four years later, in the spring of 2010, the earth-flow reached the Cervaro River valley, obstructed and strongly damaged the strategic rail corridor infrastructure connecting the Tyrrhenian and Adriatic coasts of Italy and the National Road SS90, that connects Naples to Foggia (Ventura et al., 2011; Guerriero et al., 2013).

The reported velocities of most movement, from 1954 to 2010, ranged from 1 – 2 mm/month to 2 – 5 cm/day. A sharp increase was registered during the large mobilization in both 2006 and 2010, from 1 m/day to 1 m/hour, as reported by Guerriero et al. (2013), or 5 m/day, as reported by Giordan et al. (2013).
Mostly because of the road and rail interruption and the resulting closure, the event caused severe damages not only to the local community, but also to the national railway system, especially on Southern and Central Italy.

Considerable efforts were carried by the Italian national Civil Protection Department (DPC) to tackle the emergency. Moreover, a series of actions (artificial drainages, removal of slide material from the toe, etc.) has been taking place since then, in order to mitigate the effects of the moving landslide. Notwithstanding the resulting slowdown of the earth-flow obtained, further coordinate actions are yet ongoing, in order to ensure safer conditions to the rail and road infrastructures.

In this context arose the collaboration between Italian national DPC and the Institute of Methodologies for Environmental Analysis (IMAA) of the National Research Council (CNR). In the framework of the agreement between DPC and IMAA-CNR, two field surveys were carried out in the area, one in July 2011 and one in October 2012.

The Electrical Resistivity Tomography (ERT) technique was adopted, in order to collect indirect information about the features of the landslide geometry. Data were acquired through a multi-electrode system using a Syscal R2 (Iris Instruments) device. The apparent resistivity data were inverted by the RES2DINV software (Loke, 2001) to obtain a subsurface image of the electrical resistivity pattern. All the ERT were placed perpendicularly to the landslide body and realized with a 5 m electrode spacing array that allowed to explore up 40 m in depth.

During the first field survey, on 5th-6th of July 2011, 4 ERT were carried out in the upper-zone, whereas the 5th in the lower part, at about 530 m a.s.l. (Fig. 2).

More than one year later, on 23rd-25th of October 2012, 11 ERT were realized at almost regular intervals of about 50-60 m. As explicitly required by the DPC, the attention was focused on the central part of the landslide, despite the drainage interventions, continues to move downward of some mm per day (Fig. 2).

Geological setting. In the area Miocene sedimentary rocks crop out (Guadagno et al., 2005), including:
- layered limestone, calcarenite, marly limestone, marl and argillaceous marl pertaining to the Faeto Flysch Formation, Langhian to Tortonian in age (Crostella and Vezzani, 1964),
- clay, argillaceous marl and fine sand pertaining to the Villamaina Unit, Messinian in age (D’Argenio et al., 1975).

![Fig. 2 – Electrical resistivity tomography surveys carried out on the Montaguto landslide on July 2011 (A) and October 2012 (B).](image)
The Faeto Flysch crops out in the upper and middle parts of the Rio Nocelle catchment, and the Villamaina Unit crops out in the lower part of the catchment. Quaternary alluvial sediments are present in the Cervaro River valley. In the study area, rocks exhibit a composite structural setting, reflecting a complex tectonic history (Pescatore et al., 1996; Amore et al., 1998; Di Nocera et al., 2011).

**Results.** Here we discuss only two of the sixteen ERT carried out on Montaguto landslide: the ERT 1 of both the first (July 2011) and second field surveys (October 2012) (Fig. 3).

For all the ERT carried out, the spatial variability of the electrical resistivity was quite limited. Resistivity values ranged between 3 and 40 Ω·m, that are typical values for clayey soils.

The ERT 1 carried out during the first field survey was placed in parallel to the drainage trench at a quote of 675 m a.s.l. and showed both vertical and horizontal varying resistivity (Fig. 3). More in detail, between 100 and 160 m a superficial sector relatively more resistive, about 10 m thick, likely due to the drainage trench and landslide material, was clearly identifiable. Underlying that, there was a conductive layer limited laterally by more resistive zones, probably constituted by bedrock. Finally, in the NW sector, a low resistivity zone is evident that can be interpreted as clayey or water-rich material.

The ERT 1 carried out during the second field survey (Fig. 3) was realized at about 616 m a.s.l. The electrical image showed both vertical and horizontal varying resistivity. In particular,

![ERT1 (July 2011)](image1)

![ERT1 (October 2012)](image2)

Fig. 3 – Resistivity models of ERT 1 carried out on the Montaguto landslide in July 2011 (top) and October 2012 (bottom).
between about 90 and 150 m two shallow highly resistive nuclei were present due to drainage channels. In between the two draining channels there is an almost 10 m thick layer, probably constituted by the landslide body. Underlying there is a conductive layer limited on laterally by more resistive zones, probably constituted by bedrock. Finally, both lateral sectors of the ERT showed low resistivity zones that can be interpreted as clayey or water-rich material. The lateral limit of the landslide in the NE sector could be indicated by the change between conductive and resistive material close to 165-170 m. However, this change of electrical properties could also be related with a changing lithology.

Piezometric data confirmed that the central and deeper part of the ERT can be related to a water-rich material.

**Conclusions.** Although contrasts of electrical resistivity in the ERT images were not pronounced, it was possible to observe the presence of both lateral and vertical discontinuities, that could be ascribed to lithological limits and/or to physical variation of the same material with varying water content.

In some instances, discontinuities allowed to better define the landslide geometry of deep zones, whereas this was not possible for all the ERT. Furthermore, ERT images highlighted the presence of very conductive areas, which can be an evidence of old landslide bodies and/or relatively more water saturated zones.

A synoptic view on all the ERT carried out in the area showed high conductivity properties of the deeper material between the drains and lower conductivity in the shallower part (up to 10 m). Piezometric data showed that the higher conductivity values of deeper part can be related to the higher water presence. On the other hand, the more resistive shallow part is likely to be moving material, continuously drained and thus dryer.

Is worth to underline that the analysis of the ERT here presented is preliminary, because it is only based on electrical and geo-morphological features. Future steps will focus on the analysis of direct or indirect data collected in boreholes, in order to have a better interpretation of the ERT here presented.

**References**


