Presentations including 'Albano'

POSTER SESSION

Time: 12/Sept/2023: 4:30pm-7:00pm · Location: Poster Session/Exhibition

A Multidisciplinary Approach To Assess The Kinematics Of The Pisciotta Deep-Seated Gravitational Slope Deformation (Southern Italy)

Matteo Albano[1], Michele Saroli[2,1], Lisa Beccaro[1], Fawzi Doumaz[1], Marco Moro[1], Marco Emanuele Discenza[3], Luca Del Rio[1], Matteo Rompato[2]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Italy; [2]Università degli Studi di Cassino e del Lazio meridionale, Italy; [3]Geoservizi s.r.l., Italy

Deep-Seated Gravitational Slope Deformations (DSGSD) comprise a collection of slow and complex deformational processes driven by gravity, which involve entire slopes over long time intervals [1]. These phenomena occur in various morpho-structural conditions and are characterized by typical morphological features such as double ridges, ridge-top depressions, trenches, scarps, counterscarps, and tension cracks, generally distributed along the entire ridge-slope-valley floor system. Although DSGSD rarely claim lives, they can cause significant damage to infrastructures and sometimes fail catastrophically [2].

The *Pisciotta* DSGSD represents a noteworthy example. Located along the coast of the Tyrrhenian Sea in the south of Italy, the DSGSD has been known since the 1960s. Its westward movement towards the Fiumicello riverbed manifested from the second half of the eighties [3], with mean rates of approximately 1m/year. Significant movements affected the SS447 road, connecting the *Ascea* and *Pisciotta* municipalities and crossing the DSGSD mass at its middle height, which suffered continuous planimetric and altimetric distortions, cracking and bulging of the pavement, and tilting of guardrails and retaining walls. The progressive sliding also affected the *Salerno-Reggio Calabria* railway tunnel, running on two distinct sediments and crossing the Fiumicello torrent.

The kinematics, spatial extent, and temporal behavior of the Pisciotta DSGSD were partly investigated by a few studies [3]–[5]. Therefore, we collected and analyzed data of different nature to assess the long and short-term spatial and temporal behavior of the Pisciotta DSGSD and its interaction with nearby infrastructures. We first collected geomorphological information such as structural data, high-resolution orthomosaics, and Digital Surface Models (DSM) employing Drone investigations. We then exploited high-resolution optical imagery and Synthetic Aperture Radar (SAR) satellite data from the Sentinel-1 satellite mission to assess the long- and short-term kinematics of the DSGSD body. Optical data from 1943 to 2022 were exploited by means of digital stereoscopy and Digital Image Correlation (DIC) analysis. SAR data were processed through the Small Baseline Subset (SBAS) multi-temporal method of Differential SAR Interferometry [6] to obtain ground displacement maps and displacement time series from September 2016 to October 2021. The interpretation of such data has been assisted by ancillary information consisting of topographic maps at different scales, airborne Lidar data, and ground-based measurements such as rainfall data, boreholes, and inclinometric measurements. All these data were exploited by analytical approaches to provide the best estimate of the DSGSD failure surface(s) and volume and assess its current kinematics.

All these data and analyses fully described the long- and short-term DSGSD evolution and kinematics. The in-situ surveys and the morphological analysis of historical aerial images allow inferring the onset of the DSGSD movement at approximately the middle of the second quarter of the twentieth century. The causes of the triggering of the movement are ascribable to the progressive weathering of flyschoid rocks with interbedded clay-rich layers composing the DSGSD mass, which produced a progressive movement of the slope towards the Fiumicello torrent, often accelerated by strong rainfall events. River erosion is excluded since the DSGSD is very close to the Fiumicello mouth, as well as anthropogenic forcings can be excluded since the even railway line was built before the onset of the slope movement approximately in 1889, while the odd railway track was built between 1955 and 1960 when the slope movement was still active.

From then on, we identify a first period during which the DSGSD experienced a gradual increase in displacement rate as observed by the analysis of the deformations suffered by the SR447 road. During this stage, the DSGSD expanded mainly to the southwest and developed several discrete structures, such as primary and secondary scarps, counterscarps, and linear cracks with strike-slip kinematics. The DSGSD reached maximum displacement rates in the 2006-2011 period, with mean horizontal displacement rates up to 150 cm/y as testified by inclinometric measurements performed at the end of 2009, but without undergoing a rapid collapse. Instead, the progressive stress redistribution and change of relief energy caused a gradual decrease in the displacement rate from 2006 to 2022, as testified by DIC-derived horizontal displacements, vertical displacements computed from height difference of the available Digital Elevation Models (DEM) between 1990 and 2021, and InSAR-derived vertical and horizontal (E-W) displacement rates. If such a trend is confirmed, we should expect a gradual decrease in the displacement rate until the DSGSD can eventually stop.

From a spatial point of view, the observed vertical and horizontal displacement patterns are often associated with rotational sliding. Still, translational sliding can also produce similar patterns when the slip surface is less inclined than the slope. In the latter case, the apparent vertical collapse at the landslide head relates to the opening of the landslide trench, while the uplift at the toe results from lateral slope motion. Our case is in between. The DSGSD head is affected by vertical movements, probably caused by rotational sliding. Otherwise, the uplift measured at the toe should correspond to the prevalent horizontal motion of the DSGSD. Therefore, we argue that the slope moves mainly along a roto-translational deep detachment, with several secondary shallow discrete surfaces acting as secondary detachments, as testified by inclinometric measurements.

To quantitatively understand the DSGSD behavior and its potential effects on the adjacent infrastructures, we interpreted the observed displacements through analytical approaches to reconstruct the DSGSD deep basal shear surface and volume, according to the procedure proposed by Prajapati and Jaboyedoff [7]. The obtained basal shear surface shows that the DSGSD mass reaches a maximum thickness of approximately 85 m and a volume of roughly 6.2×10^6 m^3, which is consistent with surface area-volume empirical estimates from the literature [8], [9]. Furthermore, an apparent interference is observed with the odd railway tunnel, which intercepts the DSGSD toe for approximately 60-80 meters.

References

[1] M. E. Discenza e C. Esposito, «State-of-Art and Remarks on Some Open Questions About Dsgsds: Hints from a Review of the Scientific Literature on Related Topics», *Italian Journal of Engineering Geology and Environment*, vol. 1, 2021, doi: 10.2139/ssrn.3935750.

[2] P. Lacroix, A. L. Handwerger, e G. Bièvre, «Life and death of slow-moving landslides», *Nature Reviews Earth and Environment*, vol. 1, fasc. 8, pp. 404–419, 2020, doi: 10.1038/s43017-020-0072-8.

[3] P. De Vita, M. T. Carratù, G. L. Barbera, e S. Santoro, «Kinematics and geological constraints of the slow-moving Pisciotta rock slide (southern Italy)», *Geomorphology*, vol. 201, pp. 415–429, nov. 2013, doi: 10.1016/J.GEOMORPH.2013.07.015.

[4] P. De Vita, D. Cusano, e G. La Barbera, «Complex Rainfall-Driven Kinematics of the Slow-Moving Pisciotta Rock-Slide (Cilento, Southern Italy)», in *Advancing Culture of Living with Landslides*, M. Mikoš, N. Casagli, Y. Yin, e K. Sassa, A c. di Cham: Springer International Publishing, 2017, pp. 547–556. doi: 10.1007/978-3-319-53485-5_64.

[5] M. Barbarella, M. Fiani, e A. Lugli, «Landslide monitoring using multitemporal terrestrial laser scanning for ground displacement analysis», *Geomatics, Natural Hazards and Risk*, vol. 6, fasc. 5–7, pp. 398–418, lug. 2015, doi: 10.1080/19475705.2013.863808.

[6] P. Berardino, G. Fornaro, R. Lanari, e E. Sansosti, «A new algorithm for surface deformation monitoring based on small baseline differential SAR interferograms», *IEEE Transactions on Geoscience and Remote Sensing*, vol. 40, fasc. 11, pp. 2375–2383, nov. 2002, doi: 10.1109/TGRS.2002.803792.

[7] G. Prajapati e M. Jaboyedoff, «Method to estimate the initial landslide failure surface and volumes using grid points and spline curves in MATLAB», *Landslides*, vol. 19, fasc. 12, pp. 2997–3008, dic. 2022, doi: 10.1007/s10346-022-01940-5.

[8] F. Guzzetti, F. Ardizzone, M. Cardinali, M. Rossi, e D. Valigi, «Landslide volumes and landslide mobilization rates in Umbria, central Italy», *Earth and Planetary Science Letters*, vol. 279, fasc. 3–4, pp. 222–229, mar. 2009, doi: 10.1016/J.EPSL.2009.01.005.

[9] M. Jaboyedoff, D. Carrea, M.-H. Derron, T. Oppikofer, I. M. Penna, e B. Rudaz, «A review of methods used to estimate initial landslide failure surface depths and volumes», *Engineering Geology*, vol. 267, p. 105478, mar. 2020, doi: 10.1016/j.enggeo.2020.105478.