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Strain partitioning and heterogeneous evolution in a giant slope deformation revealed by InSAR, dating and modelling

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Giant rock slope deformations in alpine environments creep slowly for long periods and may eventually evolve into catastrophic rockslides. Although structural controls on large slope instabilities are known, the influence of non-persistent interacting master fractures on their mechanisms and evolution were not been investigated. In this perspective, we studied the Corna Rossa Deep-Seated Gravitational Slope Deformation, DSGSD (Central Alps) by integrating structural analysis, space borne radar interferometry, Cosmic Ray Exposure dating (CRE) and numerical modelling. This 10 km^2 DSGSD affects a 1500 m formerly glaciated slope and is the faster DSGSD in Lombardia according to available PS/SqueeSAR^{TM} data. Here WNW-ESE trending dextral en echelon master fractures terminate and partially overlap at the Corna Rossa ridge (3000 m asl). Morpho-structural analysis and 3D geomodelling of field data show that the master fractures were re-activated by gravitational deformations with sharply different styles in: 1) a NW "sliding" sector, testified by scarps and nested rockslides; 2) a SE "spreading" sector, characterized by dominant extension accommodated by symmetric and asymmetric graben systems.

We constrained the long-term evolution of different slope sectors by CRE dating (^{10}Be and ^{26}Al) and Schmidt-Hammer exposure dating of key morpho-structures. To capture the mechanisms and activity of the DSGSD we performed SAR Differential Interferometric (D-InSAR) processing of over 100 radar images provided by the ESA Sentinel constellation. Multiple differential interferograms were computed considering long temporal baselines ($>$ 1 year) to increase the D-InSAR detection potential in the slowest sectors, as well as to mitigate the effects of snow cover in winter periods and of atmospheric artefacts. Using an original stacking procedure, surface velocity and phase gradient maps were analyzed to identify different slope sectors, their activity styles, and abrupt changes on deformation rates. Finally, to provide a mechanical explanation of field and D-InSAR data, we set up a 3D FEM elasto-plastic model of multi-stage deglaciation, including inherited master fractures as thin layers of pre-damaged rock.

Our results highlight the key role of non-persistent fractures in the evolution of the DSGSD. Their gravitational reactivation originated a "transfer zone" with strain partitioning between dominant sliding (gravitational "faults") and dominant extension (fracture overlap sector). CRE and D-InSAR data suggest that DSGSD initiated in the Lateglacial and developed graben and half-graben systems in the spreading sector. Activity along these structures ceased in Early Holocene, while the sliding sector is still undergoing progressive evolution. Our approach, integrating structural analysis and D-InSAR, allows effectively unravelling the complexity of heterogeneous deep-seated landslides and identifying key sectors in a geohazard perspective.