

1. **Research activity (max 1.000 words)**

In the hillslope evolution of tectonically active mountain landscapes Mass Rock Creep (MRC) process (Chigira, 1992) may become a primary factor for damaging rock masses so leading to slope failures that generate huge rock avalanches; it acts on large time-space scale through a continuous and non-linear variation of the tensile-deformational state of entire portions of slopes, giving rise to deformation processes known in the literature as Deep Seated Gravitational Slope Deformation (DSGSD). More, the MRC process starts at a time (t = t0) when the rock mass has already cumulated elasto-plastic strains caused by the local stress variation. It follows a phase of Primary Creep (I), in which the strain rate decreases over time (Decelerating Creep) under constant stress conditions. In general, if there is enough time, the process evolves into the Secondary Creep (II) stage, where the deformations increase with a steady trend (Steady State Creep). From the Secondary Creep stage the curve can evolve with different trends, depending on the deformation rate achieved: if it decreases, constant deformations are reached and the process is suspended; if the creep is kept constant, it remains secondary for a time that, theoretically, tends to infinity; if the applied stresses are close to the peak ones, the Secondary Creep can evolve into Tertiary Creep (III), where the strain rate increases over time until it reaches the failure (Accelerating Creep) (Saito 1992; Petley and Allison 1997), which can be anticipated in the case of transient external forcing (e.g. earthquakes).

Still, the MRC process is significantly related to the timing of landscape evolution (Bozzano et al., 2012) and earthquakes are not to be neglected as a possible cause of acceleration of deformations already in progress although they are not the most widespread type of trigger (rains and tropical storms are in first place for the triggering effect on a global scale) (e.g., Keefer, 1996; Malamud et al., 2004; Owen et al., 2008; Parker et al., 2011; Hovius et al., 2011; Li et al., 2014).

The limit of the theoretical schemes describing MRC is represented by the difficulty of precisely and accurately estimating the starting time of the process, of discriminating the distinct creeping phases, as well as determining the viscosity of the rocky matrix.In this context morpho-evolutionary analysis and landscape evolution modelling play a key role, as instruments through which it is possible to provide chronological constraints to the creep evolution of entire slopes (Bozzano et al., 2016; Della Seta et al., 2017) highlighting the predisposing and conditioning factors influencing the time-dependent process. On one hand, morpho-evolutionary analysis allows to identify phenomena of gravitational instability that affect slopes in different evolutionary stages through the analysis of accessory landforms (geomorphic markers) as a possible instrument of recognition. Moreover, it allows to reconstruct the timing of the variation of interesting valley sections from the above phenomena providing important chronological constraints through the plano-altimetric analysis and the dating of the geomorphic markers. The morpho-evolutionary investigation allows in fact, through the identification and analysis of geomorphic markers, to reconstruct the geological, geomorphological and stress history of entire morpho-structures, especially in tectonically active areas (Burbank and Anderson, 2012). On the other hand, Landscape evolution models (LEMs) have become an important numerical modelling technique for understanding the coupled tectono-geomorphic evolution of mountain belts, simulating how the earth surface evolves in response to different driving forces, including tectonics, climatic variability, and human activity (Howard, 1994). LEMs encompass empirical data and conceptual models into a set of mathematical equations that can be used to reconstruct or predict terrestrial landscape evolution and corresponding sediment fluxes (Howard, 1994).

The morpho-evolutionary and landscape evolution modelling take place in a broader multi-modelling approach aimed at analyzing the rheological evolution of a river valley slope over approximately 102 kyr (Martino et al., 2017).

Such an approach should include the three contributions described in the following list.

1) A morpho-evolutionary and landscape evolution modelling of the rock slope, based on geo-morphometric and geochronological techniques addressed to point out geomorphic markers, useful to reconstruct a temporal scanning of the main episodes and rates of morphological variations (i.e. due to the combination of tectonic offsets and erosional processes) that affected the slope-to-valley floor system.

2) A detailed engineering-geology modelling, that transposes geomechanical parameters to geological-structural features on significant geological sections adopting an equivalent continuum approach for attributing mechanical parameters to lithotechnical units. Such an approach is particularly suitable for slope-scale processes especially in addition to a geomechanical zoning that considers the statistical variability of parameters values.

3) A time-dependent stress-strain numerical modelling, performed by a sequential approach according to the main morpho-evolutionary stages of the slope. The time-dependent stress-strain analysis requires the assignment of rheological parameters that should result from a numerical calibration by means of well constrained back-analyses of already occurred failure events.

Experiencing such a multi-modelling approach allows to include in a unique methodology the back-analysis of occurred landslide events and the forecast of slope evolution by considering possible scenarios of suitable destabilizing actions (forced modelling). Moreover, the computed strain rates can be considered to establish the best solutions for slope monitoring by terrestrial or remote sensing devices.

In this regard, the general objective of my PhD research is to isolate the contribute of the geological aging (intended as the evolution of morphostructures in the direction of propagation of the orogen from the hinterland to foreland), and landscape evolution in the development of MRC time-dependent deformations. And, the specific objective is, then, to prove the relationship among the aforementioned factors through a methodological text along a transept oriented parallel to direction of the morphostructures in Lorestan, in the Zagros Mountains (Iran) from NE (older geological age) to SW (younger geological age).

1. **Research products**
2. Publications (ISI journals)

**DELCHIARO M.,** ROUHI J., DELLA SETA M., MARTINO S., DEHBOZORGI M, & NOZAEM R. (2019). *Reconstruction of river valley evolution before and after the emplacement of the giant Seymareh rock avalanche (Zagros Mts., Iran).* Earth Surface Dynamics, 7(4), 929-947. <https://doi.org/10.5194/esurf-7-929-2019>

ROUHI J., **DELCHIARO M.,** DELLA SETA M., & MARTINO S. (2019). *Emplacement kinematics of the Seymareh rock-avalanche debris (Iran) inferred by field and remote surveying.* Italian Journal of Engineering Geology and Environment. <https://doi.org/10.4408/IJEGE.2019-01.S-16>

1. Publications (NON ISI journals)

**DELCHIARO M.**, FIORAMONTI V., DELLA SETA M., CAVINATO G. P., & MATTEI M. (2020). *Fluvial inverse modelling for inferring the timing of Quaternary uplift in the Simbruini range (Central Apennines, Italy)*. Proceedings of the Geomorphometry 2020 Conference. <https://doi.org/10.30437/GEOMORPHOMETRY2020_58>

**DELCHIARO M.,** ROUHI J., DELLA SETA M., MARTINO S., NOZAEM R., & DEHBOZORGI M. (2020). *The Giant Seymareh Landslide (Zagros Mts., Iran): A Lesson for Evaluating Multi-temporal Hazard Scenarios.* In Applied Geology (pp. 209-225). Springer, Cham. <https://doi.org/10.1007/978-3-030-43953-8_13>

1. Manuscripts (submitted, in press)

**DELCHIARO M.**, FIORAMONTI V., DELLA SETA M., CAVINATO G. P., & MATTEI M. *Fluvial inverse modelling for inferring the timing of Quaternary uplift in the Simbruini range (Central Apennines, Italy)*. Transactions in GIS (submitted).

ROUHI J., **DELCHIARO M.,** DELLA SETA M., & MARTINO S. *Spatial analysis of the Seymareh (Iran) landslide debris landforms: new insights for the emplacement kinematics and the natural dam longevity.* Geomorphology (submitted).

**DELCHIARO M.**, MELE E., DELLA SETA M., MARTINO S., ESPOSITO C., & MAZZANTI P. (2020). *Quantitative investigation of a Mass Rock Creep deforming slope through A-Din SAR and geomorphometry*. V. Vilímek et al. (eds.), Understanding and Reducing Landslide Disaster Risk, ICL Contribution to Landslide Disaster Risk Reduction, https://doi.org/10.1007/978-3-030-60319-9\_18 (in press)

1. Abstracts

**DELCHIARO M.**, DELLA SETA M., & MARTINO S. (2020). *Evaluation of tectonics and landscape evolution as predisposing factor for a Mass Rock Creep deforming slope in the Zagros Belt (Iran).* Proceedings of the 2020 EGU General Assembly, Online, 4–8 May 2020, Wien, Austria. https://doi.org/10.5194/egusphere-egu2020-5239

**DELCHIARO M.**, MELE E., DELLA SETA M., MARTINO M., & MAZZANTI P. (2019). *Geomorphological investigation on the Siah-kuh Mass Rock Creep deformation (Zagros Mts., Iran) through Space-borne Synthetic Aperture Radar (SAR) interferometry and quantitative geomorphic analysis*. Proceedings of the 2019 Regional Conference on Geomorphology, 19-21 September 2019, Athens, Greece

**DELCHIARO M.**, ROUHI J., DELLA SETA M., MARTINO M., DEHBOZORGI M. & NOZAEM R. (2019). *Geostructural and geomorphic constraints for landscape evolution modeling and stress-strain numerical analysis of the giant Seymareh landslide (Zagros Mts., Iran)*. Proceedings of the 2020 EGU General Assembly, 7-12 April 2019, Wien, Austria

DELLA SETA M., **DELCHIARO M.**, MARTINO M., DEHBOZORGI M. & NOZAEM R. (2017). *Morphoevolution of the Seymareh River valley in the tectonically active Zagros Mts. (Iran): Predisposing factors and Geomorphic response to the largest landslide on the Earth surface*. Proceedings of the 9th International Conference on Geomorphology 6-11 november 2017 Vigyan Bhawan, New Delhi, India

**N.B. I dottorandi del primo anno al punto 1 possono inserire il riassunto del progetto di ricerca (max 1.000 parole)**