Date of revised Submission	February 1, 2019

IPL Project Proposal Form 2018

1. Project Title:

   The role of time-dependent rock mass deformations and landscape evolution rates as predisposing factors for massive rock slope failures

2. Main Project Fields

   Targeted Landslides: Mechanisms and Impacts

   A. Catastrophic Landslides

3. Name of Project leader

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   Core members of the Project: **Francesca Bozzano / Sapienza University of Rome – CERI Research Centre; Marta Della Seta / Sapienza University of Rome – CERI Research Centre; Salvatore Martino / Sapienza University of Rome – CERI Research Centre; Francesco Troiani / Sapienza University of Rome – Department of Earth Sciences**

4. Objectives:

   The research project, framed within an international agreement between Sapienza University of Rome and Kharazmi University of Teheran, has a two-fold objective: 1) back-analyze by means of a multi-modelling approach a representative case history to provide hints about the long-term evolution of mass rock creep (MRC) processes leading to catastrophic landslides; 2) assess the residual risk conditions in the present morpho-climatic setting, to properly address the forecasting of potential further failures resulting from the evolution of such time-dependent processes.

5. Background Justification:

   Landscape evolution of tectonically active regions encompasses geological hazard conditions related to seismicity and to the geomorphic coupling between hillslopes and rivers, with both fluvial control on hillslopes and landslide effects on the fluvial network. A wide literature exists on earthquake-induced landslides. On the other hand, few works (e.g., Della Seta et al., 2017) have focused on the role of landscape evolution rates on the development MRC. Such deformations can evolve into failures or general collapse, in most cases catastrophic rock avalanches, when the increased strain rate leads to progressive failure associated to strength reduction.

6. Study Area:

   The project will be conducted in the outer Zagros Mountains (Iran), which host the largest massive rock slope failures ever recorded on Earth surface, the Seymareh landslide.

7. Project Duration:

   The estimated duration of the research activity is 36 months

8. Resources necessary for the Project and their mobilization

Beyond the 5 researchers from Sapienza University of Rome and the joint partners from the Kharazmi University of Teheran, the Project will benefit of the collaboration of the external partner Dr. Wolfgang Schwanghart from the University of Potsdam for his expertise on numerical landscape evolution modelling. A budget of <u>60,000 €</u> will be allocated for a 24 months fellowship to be assigned to a researcher for field surveys and numerical modelling. Facilities necessary for the project will be: 1) innovative instrument for geological field surveys and components for updating already existing instruments (<u>5000 €</u>); costs for visiting of Dr. Schwanghart (<u>3000 €</u>); costs for field surveys and personnel mobility (from/to Iran) (<u>10000 €</u>); costs for dating analyses (OSL, ^{14}C) (<u>7,000 €</u>). Financial contribution from IPL could partially support the expenses for field surveys and personnel mobility

9. Project Description:

The methodological approach here proposed for landscape evolution modelling is based on: i) field surveys, geo-morphometric and geochronological techniques addressed to point out geomorphic markers of MRC deformations and active tectonics, which are useful to reconstruct a temporal scanning of the main episodes and rates of morphological variations that affect the slope-to-valley floor systems; ii) numerical landscape evolution modelling, calibrated with the field-surveyed geomorphic markers, aimed at providing well-constrained morpho-evolutionary rates of slopes affected by MRC processes; iii) time-dependent stress-strain numerical modelling of slopes, to provide back- and forward scenarios of massive rock slope failures. Geomorphic markers are represented by areal and/or linear landforms that display these three characteristics: a) a known initial, undeformed geometry; b) a known age; c) high preservation potential with respect to the time scale of the tectonic processes being studied. Among the geomorphic markers, fluvial and marine terraces are the most used ones. Landscape evolution models (LEMs) simulate the evolution of the Earth surface in response to different driving forces, such as tectonics, climate and human activity. 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. Recently, considerable improvements in landscape evolution modelling have been implemented (Campforts et al., 2017), which will be referred to in the proposed methodological approach. Stress-strain numerical modelling provides a quantification of the time-dependent behavior of rock masses, which is the result of long-term dynamic processes (i.e., after calibrating the rheological behavior based on the already occurred instabilities or of the measured strain rates referred to the ongoing slope deformations).

Rock masses with different evolutionary stages will be selected from the Zagros Mountains, where preliminary results on the Seymareh Landslide case study allowed to chronologically constrain some phases of the creep evolution and to calibrate the viscosity of the rock matrix.

10. Work Plan/Expected Results:

The research activities will be organized as follows: <u>First Year</u> - <u>1) Collection, Organization And Validation Of Available Data</u>: i) geomorphological and morpho-stratigraphic data; ii) engineering-geological data; iii) tectonic and geophysical data; <u>2) Data Base Integration</u>: existing

data will be integrated during focused geomorphological and geological surveys, to provide the database necessary for the analyses described below (<u>Milestone 1</u>); <u>3) Analytical Task 1 - Geomorphic Markers And Geo-Morphometric Analyses</u> (Research Fellow, Della Seta, Troiani): all the available generations of geomorphic markers will be mapped, correlated and interpolated through geostatistical tools (<u>Milestone 2</u>). Geo-morphometric analyses on available and/or specifically computed DEMs will be aimed at quantifying the erosion/deposition dynamics of slope-to-valley-floor systems (<u>Milestone 3</u>). <u>Second Year</u> - <u>4) Analytical Task 2 - Numerical Landscape Evolution Modelling (Research Fellow; Schwanghart)</u>: LEMs will be implemented using one of the most recently tested algorithm (TTLEM; Campforts et al., 2017), which will be calibrated using the previously surveyed geomorphic markers, to reconstruct in detail the timing and rates of morphological changes of the slope-to-valley-floor systems before and after the occurrence of massive rock slope failures (<u>Milestone 4</u>); <u>5) Analytical Task 3 - Gravitational Morphogenesis (Esposito, Martino, Bozzano)</u>: engineering-geology reference models will be built by transposing geotechnical/geomechanical data into detailed geological-structural sections (<u>Milestone 5</u>). Based on the above models, stress-strain time-dependent numerical modelling of slopes affected by MRC will be performed (<u>Milestone 6</u>); <u>6) Data Integration And Definition Of Possible Future Morpho-Evolutionary Scenarios (Milestone 7)</u>.

11. Deliverables/Time Frame:

The collection and organization of available data and its integration during field work will allow to provide an updated and homogenized GIS database at the end of the first year (<u>Deliverable 1</u>). At the same time, the 3D reconstruction of geomorphic markers dated through OSL and ^{14}C methods (<u>Deliverable 2</u>) will provide the constraints for the implementation of LEMs. The latter will provide, by the end of the second year, the continuous morpho-evolutionary scenario of the valley slopes (<u>Deliverable 3</u>) to be used as input for the stress-strain numerical modelling (Deliverable 4), to be performed both in back- and forward analysis during the third year. Data integration will finally allow to provide space-time constrained scenarios for the occurrence of massive rock slope failures on slopes presently affected by MRC.

12. Project Beneficiaries:

The methodology tuned in this project could be implemented by the technical/scientific community dealing with geo-hazard (and related risk) to better address hazard zoning and/or land-use planning in mountain environments affected by MRC processes.

13. References (Optional):

- **Della Seta M., Esposito C., Marmoni G.M., Martino S., Scarascia Mugnozza G., Troiani F. (2017). Morpho-structural evolution of the valley-slope systems and related implications on slope-scale gravitational processes: New results from the Mt. Genzana case history (Central Apennines, Italy). Geomorphology 289 (2017) 60–77**
- **Campforts, B., Schwanghart, W., and Govers, G (2017). Accurate simulation of transient landscape evolution by eliminating numerical diffusion: the TTLEM 1.0 model, Earth Surf. Dynam., 5, 47-66.**