Date of Submission	8th December 2021

IPL Project Proposal Form 2022

(MAXIMUM: 3 PAGES IN LENGTH)

1. Project Title: Deciphering the sensitivity of rock faces to climatic changes and freeze-thaw cycles in permafrost-free regions
2. Main Project Fields: A. Monitoring and Early Warning, B. Hazard Mapping, Vulnerability and Risk Assessment
3. Name of Project leader: Dr Mateja Jemec Auflič

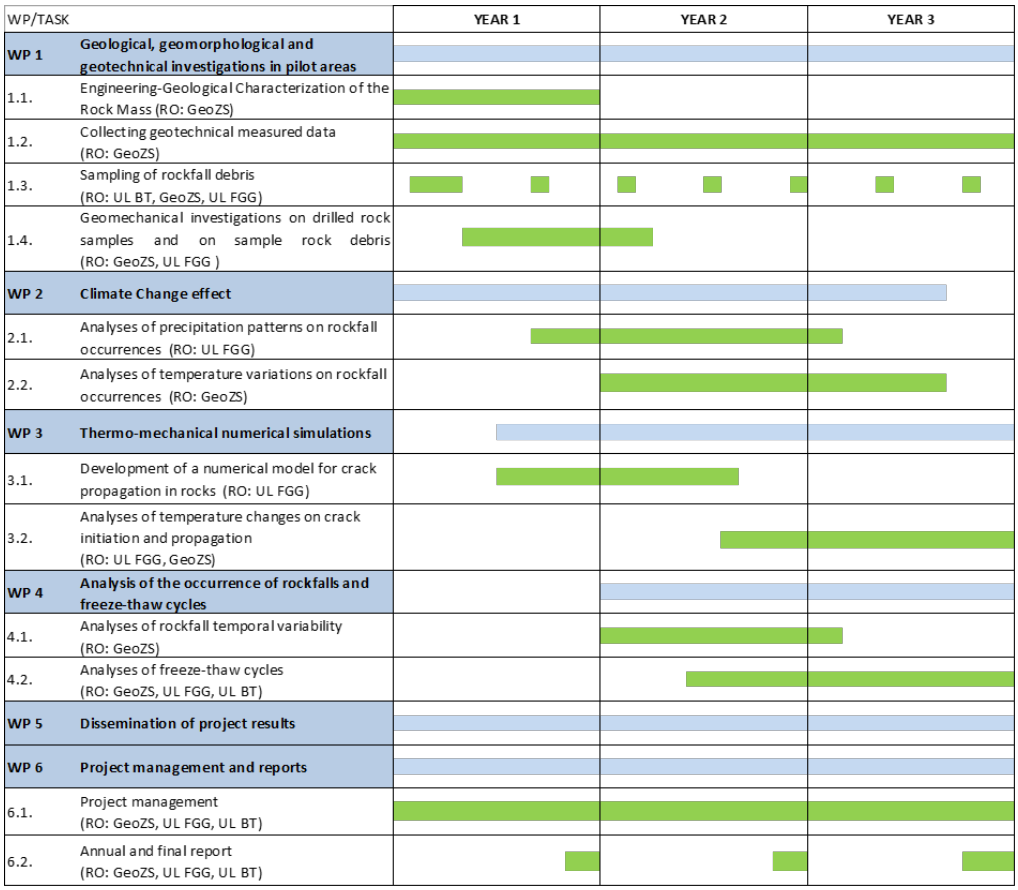
   Affiliation: Geological Information Centre, Geological Survey of Slovenia

   Contact: Dimičeva ulica 14, SI-1000 Ljubljana, Slovenia, Mobile: +38631717099, E-mail: mateja.jemec@geo-zs.si

   Core members of the Project: Tina Peternel, PhD (GeoZS), Jernej Jež, PhD (GeoZS), Prof. Matjaž Mikoš (UL FGG), Assist. Prof. Nejc Bezak (UL FGG)
4. Objectives: The main objective of the proposed project is to decipher the sensitivity of rock faces to climatic changes and variations in freeze-thaw cycles in permafrost-free regions. In order to achieve this objective, we will apply a multi-method approach consisting of in-situ measurements, observations and monitoring that will allow us to determine the initial state of rock instability, the associated rockfall volume and its frequency, and the near-surface rock temperature.
5. Background Justification: Rockfalls are result of a long geological process (tectonics, weathering, etc.), but the fall is sudden. The questions most often asked are what trigger a rockfall (what causal factors) and how it happens (what mechanisms)? In the case of a meteorological factor, several physical mechanisms may be involved, which may manifest as rockfalls initiated by a slide or a fall. The periodic freeze-thaw cycles induce the joint cracks to expand continuously, which will lead to the failure of the rock mass. Thermal shock occurs due to rapid temperature change which leads to significant variation of stresses and displacements in brittle rocks. In transient heat flow, rapid cooling leads to large tensile stresses at the surface, while rapid heating causes large compressive stresses. The redistribution of stresses can lead to the appearance of microcracks, and the development of microcracks can lead to the failure of a rock face.
6. Study Area: In the proposed project, we will study sensitivity of rock faces to climate changes and variations in freeze-thaw cycles in two pilot areas in eastern part of Slovenia.
7. Project Duration: 3 years (October 1, 2021 – September 30, 2024)
8. Resources necessary for the Project and their mobilization: The total project budget is 300.000 EUR, approved in 2021 by Slovenian Research Agency, covering materials and personnel costs for 50 man-months (principal researchers from GeoZS, research collaboration with UL FGG).
9. Project Description: In the proposed project, we attempt to focus on deciphering the sensitivity of rock faces to climatic changes and freeze-thaw cycles in permafrost-free regions, applying multi method

approach. There is an increasing concern that rising air temperatures and intensive rainfall may affect slope stability not only in high mountain regions but also in permafrost-free areas. In term of identifying of the research problem, we will focus on two hypotheses. The first is that climate change has an impact on rockfalls in permafrost-free regions and the second is the change of near-surface rock temperature affect the expansion of joint cracks. To decipher the sensitivity of rock faces to climate change and freeze-thaw cycles in permafrost-free areas, we will consider the following key parameters: engineering-geological conditions of the rock faces (engineering-geological units, spacing of discontinuities, aperture of joints, infill, weathering, compressive strength, orientation of discontinuities, determination of mechanical properties); geotechnical monitoring (crack propagation patterns); climate change scenarios (historical and future projections). Monitoring areas are selected based on the following criteria: frequency of rockfalls, risk to population and infrastructure, and diversity of rock composition (carbonate and igneous rocks). We will study the sensitivity of rock faces to climate change and variations in freeze-thaw cycles. Each individual rock type has different engineering properties and predisposing factors that may affect exfoliation, discontinuity formation and fractures. However, the type of bedrock, its mineralogical setting, anisotropy, or isotropy very often determine the susceptibility to fracture formation and subsequent opening. The study will allow us to decipher the sensitivity to climate change and freeze-thaw cycles in two different rock types in permafrost-free areas. Pilot monitoring areas have already been equipped with geotechnical sensors (rain gauges, sensors for air temperature and humidity, tiltmeters, kit for measuring rock stress and deformability, laser distance gauges, crackmeters and near-surface rock temperature sensors). The results will also directly confirm or reject the postulated hypotheses and provide new insights into rock mechanics. In addition, the results of the proposed project will fill the gap in scientific knowledge of the impacts of climate change in permafrost-free regions, which are rarely the subject of scientific studies.

10. Work Plan/Expected Results: The structure of the proposed 3-year research project consists of 6 Work Packages and two compulsory Work Packages (5 and 6) that are included in the rest of Work Packages:
    WP1 Geological, geomorphological and geotechnical investigations in pilot areas
    WP2 Climate Change effect
    WP3 Thermo-mechanical numerical simulations
    WP4 Analysis of the occurrence of rockfalls and freeze-thaw cycles
    WP5 Dissemination of project results
    WP6 Project management and reports
    A detailed plan for the implementation of each work package of the project, timetable for the 3 years is shown in Table 1.
    Table 1: A detailed plan for the implementation of each work package of the project



11. Deliverables/Time Frame: We start the project with WP 1, which includes the engineering geological characterization of the rock faces, sampling of rockfall debris and rocks. In the first year (2021-2022), we will also begin WP2. WP3, task 3.1 will start in the first year of the project and will be completed in the second half of the second year (in 2023). After that, Task 3.2 will start and will be completed at the end of the project (in 2024). At the beginning of the second year, we will start with tasks 2.2 and 4.1, followed by task 4.2 which will continue until the end of the project. Based on the results obtained in the tasks of WP 2, WP 3 and WP 4, we will confirm or reject the research hypotheses. As part of the dissemination of the project results (WP 5), we will present the obtained results at international scientific conferences (e.g. EGU, WLF, ReSyLAB, etc.) and as original papers in international journals (e.g. Science, Landslides). The tasks outlined in WP 6 will take place throughout the project.
12. Project Beneficiaries: Civil protection administration, Slovenian Infrastructure Agency, local authorities, Slovenian Railways operator, Ministry for the Environment and Spatial Planning
13. References (Optional): https://glvn.geo-zs.si/