Date of Submission	4 June 2025

IPL Project (IPL - 262) Annual Report Form

Period of activity under report
from 1 January 2024 to 31 December 2024

1. Project Number (approved year) and Title:

   IPL – 262 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

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   Core members of the Project: Names/Affiliations: 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. Study Area: We study sensitivity of rock faces to climate changes and variations in freeze-thaw cycles in five pilot areas in eastern part of Slovenia.

6. Project Duration: 3 years (October 1, 2021 – September 30, 2025)

7. Report

1) Progress in the project: This year we explore the impact of rock temperature on rock deformation in temperate, non-permafrost conditions, with a focus on crack initiation and behavior in natural environments. Monitoring was conducted at seven exposed rock faces across the Alpine and Prealpine regions of Slovenia (Eastern Alps). Strain gauges with integrated temperature sensors were installed in boreholes at three different depths to track specific deformations in the rock faces over a four-year period. Both reversible and irreversible rock deformations were observed,

driven by temperature fluctuations. Reversible deformations were most prevalent when rock temperatures were near or below 0°C, occurring predominantly between October and May. Rather than thermal shock resulting from extreme temperature changes, thermal fatigue induced by repeated freeze-thaw cycles—combined with the presence of water in pores and microcracks—led to irreversible rock deformation, which was measured and observed in situ. While rock temperature near the surface influenced deeper deformation patterns, the generally low thermal conductivity of rocks limited the effect of air temperature on deeper rock layers. As a result, most thermally induced cracks are expected to form at shallower depths within the rock face.

2) Beneficiaries of Project for Science, Education and/or Society: Civil protection administration, Slovenian Infrastructure Agency, local authorities, Slovenian Railways operator, Ministry for the Environment and Spatial Planning

3) Results: (15 line maximum, e.g. publications)

   By monitoring the precondition factors that can lead to rockfall, we have come one step closer to rockfall observatory in Slovenia. Monitoirng data will be used to understand the complex rock environment and help to drive numerical and statistical models to provide tools for predictions. The overall results can be in effective translation of this scientific advances into useful knowldege transforms which will be basis for political decision to better meet the societal and environmental needs.

   Published papers:

DUJC, Jaka, JEMEC AUFLIČ, Mateja. Automated FEM-based determination of thermal diffusivity and temperature profile for rockfall prediction. V: FRANCIS, Adel (ur.), MIRESCO, Edmond (ur.), MELHADO, Silvio (ur.). Advances in information technology in civil and building engineering : proceedings of ICCCBE 2024. Vol. 2, Simulation and automation. Cham: Springer, cop. 2025. Str. 498–505, ilustr. Lecture notes in civil engineering (Online), vol. 628. ISBN 978-3-031-87364-5. ISSN 2366-2565. https://link.springer.com/chapter/10.1007/978-3-031-87364-5_42, DOI: 10.1007/978-3-031-87364-5_42.

JEMEC AUFLIČ, Mateja, ŠEGINA, Ela, VIHTELIČ, Andrej, ŠINIGOJ, Jasna. Towards observatory for rockfalls in Slovenia. V: SCHNEIDER, Joseph (ur.). Interpraevent 2024 : conference proceedings : June 13th, 2024, June 14th – 16th, 2024, Vienna, Austria. Klagenfurt: International Research Society Interpraevent, 2024. Str. 476-479. ISBN 978-3-901164-32-3

ŠEGINA, Ela, JEMEC AUFLIČ, Mateja, MIKOŠ, Matjaž, BEZAK, Nejc. A preliminary investigation of the small rockfall triggering conditions along a road network in Slovenia.

Landslides : Journal of the international consortium on landslides. [Print ed.]. 2024, letn. xx, št. xx, 13 str., ilustr. ISSN 1612-510X. https://link.springer.com/article/10.1007/s10346-024-02302-z, DOI: 10.1007/s10346-024-02302-z.

JEMEC AUFLIČ, Mateja, BEZAK, Nejc, ŠEGINA, Ela, FRANTAR, Peter, GARIANO, Stefano Luigi, MEDVED, Anže, PETERNEL, Tina. Climate change increases the number of landslides at the juncture of the Alpine, Pannonian and Mediterranean regions. Scientific reports. 2023, vol. 13, 14 str. ISSN 2045-2322. DiRROS - Digitalni repozitorij raziskovalnih organizacij Slovenije, DOI: 10.1038/s41598-023-50314-x.

JEMEC AUFLIČ, Mateja, ŠEGINA, Ela, VIHTELIČ, Andrej, ŠINIGOJ, Jasna. Towards observatory for rockfalls in Slovenia. V: INTERPRAEVENT 2024 : Vienna, Austria : conference proceedings. Klagenfurt: INTERPRAEVENT, 2024. Str. 476-479. ISBN 978-3-901164-32-3.

JEMEC AUFLIČ, Mateja, ŠEGINA, Ela, PETERNEL, Tina, ZUPAN, Matija, JEŽ, Jernej, ŽEBRE, Manja, KRALJ, Polona, ZAJC, Marjana, MIKOŠ, Matjaž, BEZAK, Nejc, KOBAL, Milan. Monitoring of rockfall prone areas in eastern Slovenia. V: PERANIĆ, Josip (ur.), et al. Landslide modelling & applications : proceedings of the 5th Regional Symposium on Landslides in the Adriatic-Balkan Region : [23-26 March 2022, Rijeka]. Rijeka: Faculty of Civil Engineering, University of Rijeka; Zagreb: Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, 2022. Str. 75-79.