Geophysical Research Abstracts
Vol. 18, EGU2016-14256, 2016
EGU General Assembly 2016

Decay of sandstone monuments in Petra (Jordan): Gravity-induced stress as a stabilizing factor

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As demonstrated by physical experiments and numerical modeling the gravity-induced stress (stress in further text) in sandstone massive reduces weathering and erosion rate (Bruthans et al. 2014). This finding is in contrast to common view that stress threatens stability of man-made monuments carved to sandstone. Certain low- levels of gravity-induced stress can in fact stabilize and protect these forms against weathering and disintegration. The purpose of this investigation is to evaluate the effect of the stress on weathering of sandstone monuments at the Petra World Heritage Site in Jordan via field observations, salt weathering experiments, and physical and numerical modeling. Previous studies on weathering of Petra monuments have neglected the impact of stress, but the ubiquitous presence of stress-controlled landforms in Petra suggests that it has a substantial effect on weathering and erosion processes on man-made monuments and natural surfaces. Laboratory salt weathering experiments with cubes of Umm Ishrin sandstone from Petra demonstrated the inverse relationship between stress magnitude and decay rate. Physical modeling with Strelec locked sand from the Czech Republic was used to simulate weathering and decay of Petra monuments. Sharp forms subjected to water erosion decayed to rounded shapes strikingly similar to tombs in Petra subjected to more than 2000 years of weathering and erosion. The physical modeling results enabled visualization of the recession of monument surfaces in high spatial and temporal resolution and indicate that the recession rate of Petra monuments is far from constant both in space and time. Numerical modeling of stress fields confirms the physical modeling results. This novel approach to investigate weathering clearly demonstrates that increased stress decreases the decay rate of Petra monuments. To properly delineate the endangered zones of monuments, the potential damage caused by weathering agents should be combined with stress modeling and verified by documentation of real damage.

This research was funded by Grant Agency of Charles University (no. 386815)

Bruthans J., Soukup J., Vaculíková J., Filippi M., Schweigstillova J., Mayo A.L., Mašín D., Kletetschka G.,Řihošek J. (2014): Sandstone landforms shaped by negative feedback between stress and erosion. Nature Geoscience 7(8): 597-601.