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Field and laboratory rainfall simulation as a tool to investigate Quaternary badland geomorphic development

Nikolaus Kuhn (1), Milica Kasanin-Grubin (2), Aaron Yair (3), Brian Rorke (4), and Wolfgang Schwanghart (1)

(1) Department of Environmental Sciences, University of Basel, Switzerland (nikolaus.kuhn@unibas.ch / Fax: +41-61-2670740 / Phone: +41-61-2670741), (2) Faculty of Environmental Governance, Educons Univesity, Sremska Kamenica, Serbia Department of Geography, Hebrew University, Israe, (3) Department of Geography, Hebrew University Jerusalem, Mt Scopus Campus, Jerusalem, Israel, (4) Soil Erosion Laboratory, University of Toronto, Canada

Badlands are traditionally considered as natural analogue experiments of landscape development. Commonly, their morphology is linked to lithological properties of the bedrock. However, recent investigations indicate that the geomorphic development is sensitive to climate and in particular to precipitation characteristics. This sensitivity enables the combination of rainfall simulation experiments with numerical models to study the relevance of climate change for their long-term geomorphic development. In this study, the relevance of precipitation characteristics for the Quaternary landscape development in the Dinosaur Badlands in Alberta, Canada, and Zin Valley Badlands, Negev Desert, Israel is investigated. Runoff, erosion and weathering were simulated in the field and the laboratory to determine rates for modeling different precipitation regimes. Based on the results, a numerical model was developed and the effects of changing precipitation characteristics (rainfall, snow cover and melt) on long-term landscape development were simulated.

In the Dinosoaur badlands, weathering and erosion experiments show that the balance between snowmelt induced weathering in the spring, summer rainfall, and erosion determines the rate of slope retreat. In the Zin Valley, on the other hand, the magnitude of the individual rainstorms determines whether a slope section is eroded or acts as a runoff and sediment sink. As a consequence, in the Zin Valley badland slopes experienced an auto-stabilization during the Quaternary. In the Dinosaur Badlands, on the other hand, Holocene climatic variations do not appear to have caused a permanent differentiation of patterns of erosion and deposition. Based on these results the reaction of badland slopes to changing precipitation characteristics was modeled. The model shows that both badland slope systems are currently fairly stable against climate change in the range of variations in rainfall characteristics experienced during the Holocene. However, the stability is achieved in different ways. In the Dinosaur Badlands, weathering rates are low compared to erosion capacity, maintaining continuous evacuation of sediment from slopes to the flood planes of the Red Deer River system. Only a very pronounced contrast between winter weathering and drier summers would generate a colluvium and thus change slope hydrology. In the Zin Valley, the development of a thick colluvium at the foot of the slopes has increased infiltration capacity, reducing runoff and sediment yield into the floodplain. Only an increase in rainfall magnitude would improve runoff continuity and induce the erosion of the colluvium. The somewhat surprising, long-term resilience of the badland slope systems identified in this study illustrates the versatility combining rainfall simulation experiments with numerical modeling in landscape evolution studies.