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Experimental investigation into Quaternary badland geomorphic development

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Badland morphology is commonly 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.

In this study, the precipitation characteristics that are critical for the Quaternary landscape development in the Dinosaur Badlands in Alberta, Canada, and Zin Valley Badlands, Negev Desert, Israel are investigated. Runoff, erosion and weathering were simulated in the field and the laboratory to determine rates for modeling different precipitation regimes.

Currently, the geomorphic development in the Dinosaur badlands is characterized by weathering/supply limited conditions, leading to slope retreat independent of lithology. In the Negev, transport limited conditions cause frequent runoff discontinuity, creating a pattern of areas dominated by erosion or deposition.

The results of the weathering and erosion experiments show that the balance between snowmelt induced weathering in the spring and summer rainfall and erosion determine the rate of slope retreat in the Dinosaur Badlands. 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 sediment sink. The experiments illustrate that the badland slopes experienced an auto-stabilization during the Quaternary in the Zin Valley. In the Dinosaur Badlands Holocene climatic variations have not 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. In their current state, both badland slope systems appear to be fairly stable against climate change in the range of those occurring 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. Here, only an increase in rainfall magnitude would improve runoff continuity and induce the erosion of the colluvium. This would in turn reduce infiltration capacity and thus initiate a positive feedback on runoff and sediment yield into the Zin River.

Overall, Holocene climate change appears to be insufficient to change the geomorphic development in both badlands. However, this stability is achieved not despite of climate, but because of the specific history of geomorphic development. In addition, the combination of erosion and weathering experiments with numerical modeling demonstrates the versatility of Experimental Geomorphology in landscape evolution studies.