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Research paper

# A disaster waiting to happen—On the dynamic relations between geological processes and development in a desert environment

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## HIGHLIGHTS

- We present the first comprehensive analysis of the specific site and complexities.
- Combined analysis of aerial photos, photogrammetric data, GIS, ground observations.
- Clear causality between geology, design, practices, and potential disaster.
- We propose general construction guidelines for similar environments.
- We propose actions to mitigate gradual developments, and those of an imminent earthquake.

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## ABSTRACT

The paper reviews the dynamic relations between geology, soil mechanics, planning and construction in a desert environment. It claims that misunderstanding environmental processes, disregarding geological properties and climatic uncertainties, while planning for construction and development, can have decisive outcomes of potentially catastrophic implications, such as destabilizing the very terrain on which a project is built. To make this point, it reviews the evolution of a relatively small settlement located in the arid Negev Desert Highlands, Israel, and the way this has affected the very cliff on which it is built.



## 1. Introduction

What is the probability that a desert settlement be threatened by water-induced stability problems? Small to none, one might think. Yet the truth could not be less predictable. Deserts tend to have their own soil and climate peculiarities. The specific desert dealt with in this paper, especially the area on which the case study campus is located, is characterized by lithosols and regosols, aeolian, alluvial and marine sediments, rocky outcrops and cemented conglomerates. This part of the Negev Desert Highlands located approx. 50 km south of Beer Sheva (Fig. 1) is defined as arid and receives a yearly average precipitation of approx. 90 mm, unevenly spread through the winter months October–March, concentrated in a few downpours. The annual variability index is high, estimated between 6.0 (Evenari, Shanan, & Tadmor, 1971) and over 7 (33-year measurements, ranging between 23 and 167 mm; Bitan & Rubin, 1994; Stern, Gradus, Meir, Krakover, & Tsoar, 1986). Once in 10 years rainfall is expected to surpass 160 mm. There are about 25 days of rain per year (with more than 0.1 mm), with the maximum daily rainfall registered until the early 1990s being 44 mm (Bitan & Rubin, 1994). This rain regime, combined with the specific soil types, creates very quickly an almost impermeable swollen upper crust of the loess soil, on which the falling drops become surface runoff, often resulting in violent flash floods in the dry riverbeds and canyons. However, if given time, water accumulating in terrain depressions will slowly percolate into the soil.

Whereas the surface runoff and floods cause accelerated surface erosion, rill and gully incision and headcut migrations (Avni, 2005; Poesen, Nachtergaele, Verstraeten, & Valentin, 2003; Poesen et al., 2002), the water that percolates to the lower strata can be as

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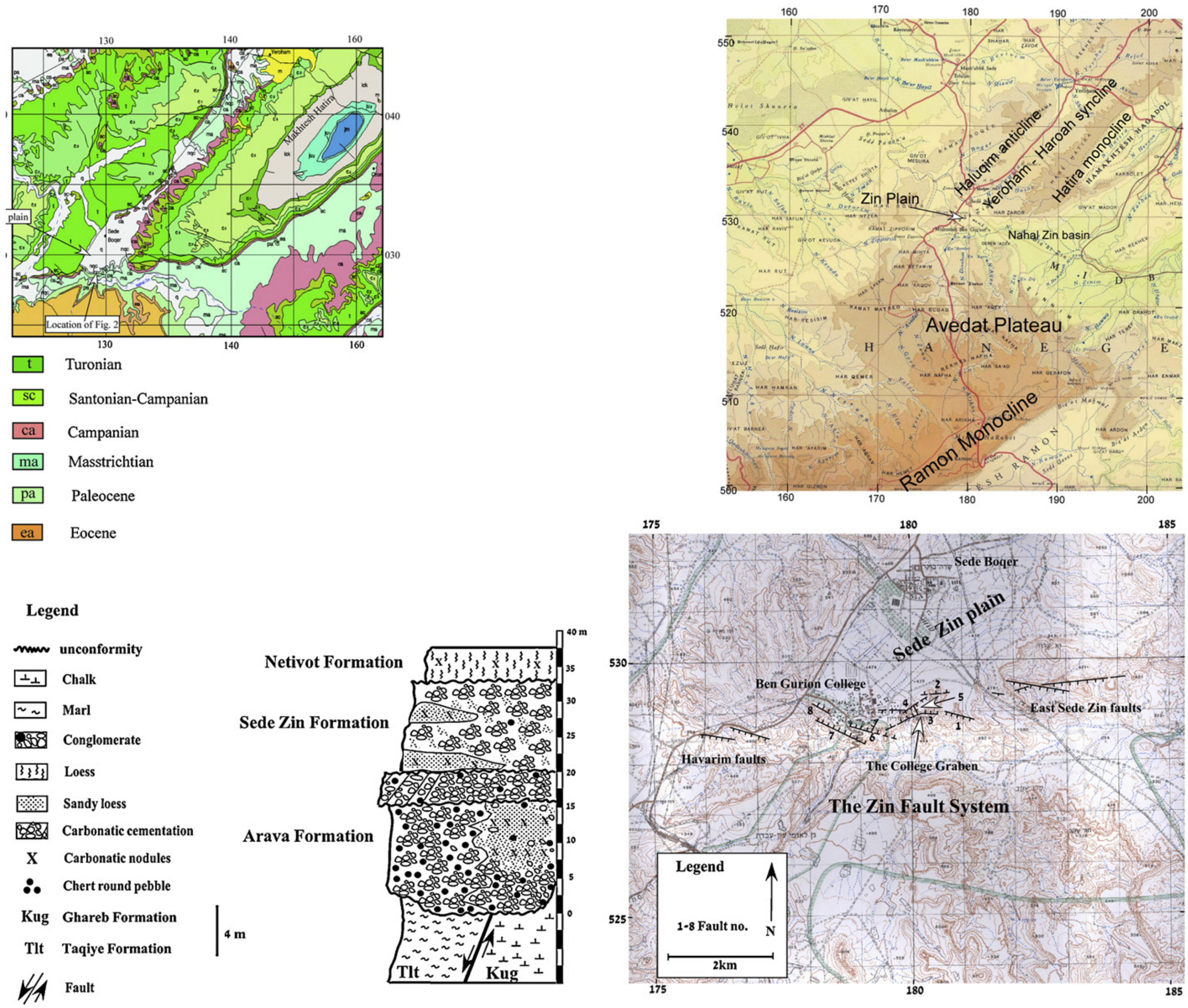


**Fig. 1.** (a) (Right, up) Avedat Plateau, Zin Plain, synclines, anticlines and monoclines. (b) (Right, down) The Zin fault system geological map. (c) (Left, up) Geological map of case study region (after Sneh, Bartov, Weissbrod, & Rosensaft, 1998). (d) (Left, down) Typical section of case study area, location marked in map as location of Fig. 2.

dangerous, if not more so, when it reaches clay and marl layers which, once wet, will apply pressures on the upper strata or cause lateral movement, occasionally even rock falls and landslides when adjacent to a cliff. This process is well known on global scale, even in arid and semi-arid environments, and has been widely described in the literature (Godfrey, Everitt, & Duque, 2008; Gutierrez Elorza & Martinez, 2001; Gutierrez Elorza, Sancho, & Arauzo, 1998).

This simplistic description of geology, soil properties and mechanics, seems to have been systematically disregarded in the specific case study presented here, the Sede Boqer Campus, which should nevertheless be regarded as indicative of many other cases in deserts and drylands. In the specific case study the outcome of this disregard has come to endanger the very existence of part of the settlement itself. However, on a broader scale such occurrences may become much more common as deserts expand through desertification processes, and an ever increasing number of people find themselves within deserts and under a climatic instability, in which extremes become more extreme and more frequent.

## 2. Aims and methods

The authors of this paper have a long personal and immediate acquaintance with the specific campus and its broader geographic context, which they have been living in and researching for over 25 years. Through this intensive daily acquaintance with the region's peculiarities, but also through a continuous long-term observation of processes and changes, we have developed a critical perspective of the dynamic interaction between development processes (e.g., settlement activity, construction, paving, landscaping and irrigation) and the immediate natural settings. This long term exposure to the processes briefly described above guided us to systematically investigate and record them, to allow an assessment of the impact of potential developments in the near future, as well as warn against similar developments in geoclimatic settings with similar constraints.

In researching this paper we reviewed all available technical reports, soil surveys, construction plans, and aerial images. Due to the nature of the material, most of the surveys and reports are in Hebrew, yet they have been included