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Geomorphic Response to Quaternary Environmental Changes in the Wadi Mujib Canyon (Jordan)

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ABSTRACT. The preliminary results of an ongoing research project on the geomorphology and the Quaternary geology of the Wadi Mujib Canyon in Jordan are presented. Deep incision of the canyon in the Cretaceous marine sediments of the Jordanian plateau took place in the last 5 to 6 million years as part of the tectonical development of the Dead Sea Rift. Tectonics play a major role in the geomorphological development (through huge mass movements, a.o.) of the canyon but several geomorphological indicators (travertines, river terraces, periglacial-type slope deposits, etc.) testify of important climatic shifts (alternation of warm arid phases with cooler Pluvials) which took place during the Quaternary.

KEY WORDS: Dead Sea Rift, tectonics, Quaternary, mass movements, travertine, river terrace, periglacial-type slope deposits, absolute datings.

Introduction

This paper presents preliminary results of a research project titled "Geomorphology and Quaternary Geology of the Wadi Mujib Canyon (Jordan)" (Homes-Frédéricq et al., 1997; De Jaeger et al., 1999; De Jaeger and Risack, 1999; De Jaeger et al., 2000).

The Wadi Mujib, flowing in Jordan from east to west into the Dead Sea (-410 m b.s.l.), has eroded one of the most impressive canyon systems over the world with a mean valley depth of 600 m. The Dead Sea Rift is a part of the 6000 km long East African Rift, that runs from Mozambique up to southern Turkey. Most authors agree that intensive tectonic movements started about 30 million years ago, during the Late Tertiary (Late Oligocene/Early Miocene) (Freund et al., 1970; Garfunkel, 1970; Ben-Avraham and Ten Brink, 1989; Ginat et al., 1998). Following these first movements, the Cretaceous marine sediments (limestone, chert, marl, chalk intercalated with gypsum evaporitic layers) of west central Jordan were uplifted. According to Abed (1985a) the Mujib area in particular must have been subjected to uplifting phases yet from the Lower Cenomanian on, becoming an island in the region, followed by phases of sub-

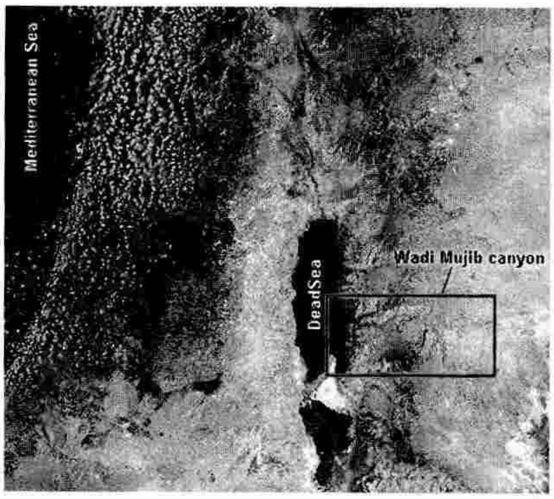

Fig. 1. Situation of the Wadi Mujib canyon in Jordan (Landsat MSS, 1992).

Fig. 2. The bare slopes of the canyon characterized by often huge mass movements.

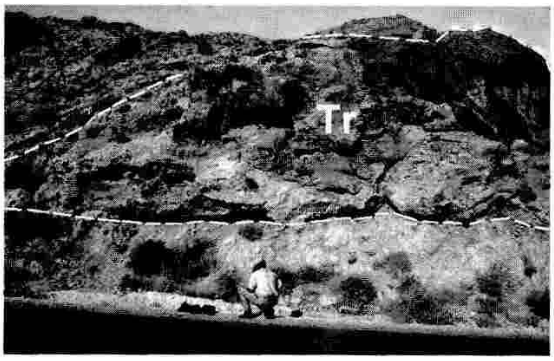

Fig. 3. Relict travertine deposit (Tr).

sidence (thick Late Cretaceous sediments). However, due to renewed uplift in the Late Tertiary, a young tableland (circa 700–800 m a.s.l.) was formed through which the proto-Wadi Mujib incised a small valley. At the same time, the sinistral strike-slip fault system, along which the Dead Sea is situated now as a kind of a pull-apart basin, was very active. The deep incision of the canyon of the Wadi Mujib started only at 5 to 6 Ma, after several Late Pliocene fissure eruptions resulting in basalt sheets spread across the plateau (dated by Barbieri et al., 1979). Such a vigorous incision through thick marine sediments in such a short time span was possible due to the high relief energy resulting from the combined plateau uplift and base-level drop (Fig. 1).

Geomorphological indicators for Quaternary environmental changes

The strong Plio-Pleistocene erosion which was necessary for the formation of the deep canyon took place in the time of alternating climatic conditions; a dominantly arid to semi-arid climate was interrupted by several Pluvials (Burdon, 1959; Abed, 1985b; Shehadeh, 1985; LaBianca and Lacelle, 1986). These pluvial periods correspond to the 'European' Glacial periods of the Pleistocene and are characterized in the Near East by higher amounts of precipitation. Especially during the well developed Pluvials which correspond to the Riss and Mindel Glacials, we can expect that the fluvial erosion through the uplifted Mujib area was extremely high. The last Pluvial (corresponding to the Würm Glacial) was characterized by the development of the Lisan Lake which filled a large part of the Dead Sea Rift up to a level of -180 m b.s.l. (Begin et al., 1974). From the Holocene on the climate in the area was characterized by dry to extremely dry periods, being interrupted by gradually shorter and less humid phases (Neev and Emery, 1995).

Several geomorphological indicators such as huge mass movements (De Jaeger et al., 1999; De Jaeger and Risack, 1999), travertine deposits, periglacial-type slope deposits and fluvial terrace remnants were observed during field surveys. They all argue for fluctuating environmental conditions through the Quaternary. These are sometimes related to neotectonic movements (Fig. 2: mass movements, Fig. 3: relict travertine deposits due to drop of the water table and subsequent drying of seepage lines, Fig. 4: T2), but no less observations lead to the conclusion that periods of higher precipitation and lower temperatures (Fig. 4: T1; Fig. 5: periglacial-type slides and flows of basalt cobbles) alternated with dry and warm periods.

Further research and conclusions

Several geomorphological indicators testify to changing environmental conditions which took place during the Quaternary in the deep canyon of the Wadi Mujib. Part of the geomorphological evolution is undoubtedly linked to the active tectonic evolution of the Dead Sea Rift but an even greater part is due to changing climatic conditions.

The further field research will be focused on the relative and absolute dating of landforms and correlated sediments in order to reconstruct the geomorphological evolution of the Wadi Mujib Canyon and on the unravelment of the respective roles of tectonic forces and Quaternary climatic changes.

During a field campaign in October 2000, samples will be taken for absolute dating of 'key' elements in the canyon: travertine, river terrace sediments, rock varnish/ patina developed on the basalt cobbles which compose the supposedly LGM periglacial-type slides and flows. This field research will be conducted in collaboration with Dr. Alan Watchman, School of Anthropology and Archaeology, James Cook University, Townsville, Queensland, Australia.

Travertine and fluvial sediments will be dated by U-series and OSL, respectively. Rock varnish/ patina can be dated by AMS ^{14}C of carbon-bearing substances 'catched' in the var-

'ig. 4. River terraces: T0 (actual formation), T1 (estimated as a Late Pleistocene formation related to the Lisan lake) and T2 (oldest and huge alluvial accumulation, probably the result of Middle Pleistocene block faulting).

Fig. 5. Stabilized slopes covered by probably periglacial basalt slides and flows (b).

ish/patina during their formation (Watchman, 1994); it is well ossible that the latter datings offer only a *terminus ante quem*. owever, dating of the rock varnish/patina will allow us to as- ss the minimum age of the stabilisation of the slopes covered y periglacial-type scree.

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