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Quaternary evolution of the Marrakech High Atlas and morphotectonic evidence of activity along the Tizi N'Test Fault, Morocco

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ABSTRACT

Here, we consider the Ourika and Rheraia drainage basins on the Tizi N'Test Fault zone in the mountains of the Marrakech High Atlas (western Morocco) with regard to Late Pleistocene tectonic activity. New insights into geomorphological changes in drainage patterns and related landforms are based on geological fieldwork in conjunction with DEM analysis. Lithological and structural data combined with certain geomorphometric indices provide clues to the ongoing uplift of Quarternary surfaces in this region. Five geomorphological indices are utilized: 1) drainage network, 2) shape of stream long profiles, 3) hypsometric integral and curves, 4) valley-floor width valley-height ratio (Vf index), and 5) stream gradient index (SL index). We also considered the temporal evolution of alluvial-deposit complexes with diverse lithofacies, such as debris flows, channel gravels, rockslide-debris avalanche, stratified slope deposits, terrace gravels, and fan deposits in the Ourika and Rheraia valleys. Pleistocene talus deposits and fluvial sediments are offset by the Tizi N'Test Fault in the Upper Ourika and Upper Rheraia valleys. Such deformation of thick, continental deposits strongly points to thrust reactivation along the Tizi N'Test Fault. We define the chronology and overall aggradation phases, or lateral incision phases, showing how they are the consequences of variations in tectonic uplift and climate. As a result, we are better able to access recent morphotectonic evolution in part of the Marrakech High Atlas.

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1. Introduction

The northern flank of the Marrakech High Atlas (MHA) is located in an active compressionnal setting. Analysis of landforms dynamics constitutes a tool with which to constrain recent tectonic activity (e.g., Rockwell et al., 1985; Wells et al., 1988; Burbank and Anderson, 2000; Keller and Pinter, 2002; Molin et al., 2004). Geomorphic indices classically used as tools to identify areas experiencing active deformation are: stream-gradient, hypsometric curves and integral, drainage basin asymmetry, stream-gradient index, mountain front sinuosity and ratio of valley floor width to valley height (Merritts and Vincent, 1989; Keller and Pinter, 1996). This approach involves morphometric analysis of selected landforms and drainage pattern to evaluate the differential incision domains.

In the MHA North Front, Pleistocene tectonic activity has been evidenced for the 25 years (Dutour and Ferrandini, 1985; Missenard et al., 2007) but no significant information has been supplied on recent morphotectonic evolution either of the northern range or the axial zone of the MHA.

Detailed characterization and differentiation of the alluvial units, are provided through analysis of aerial photographs, DEM and field studies in the Ourika and Rheraia drainage basins. This approach allowed us to develop a basic geodynamic model showing the effect of tectonic activity on geomorphology and landscape evolution.

The study of Quaternary surface deposits was combined with a detailed examination of two key sites along the main active branch of the Tizi N'Test Fault Zone (TTFZ) : 1) the Tourcht Valley site, on the right bank of the Ourika High Valley; and 2) the Aït Souka Valley site, on the left bank of the Rheraia river High Valley.

In order to establish how the modern geomorphological features represent a rapid response to tectonic motion located mainly along the TTFZ, we describe and interpret: i) the morphometry, ii) the drainage patterns, and iii) the stratigraphy of Quaternary surfaces deposits associated with recent deformation along the TTFZ. We show that these deposits constitute reliable chronological indicators for the uplift of the basement.

2. Geomorphic and geologic settings

The Marrakech High Atlas (MHA) is the most prominent topographic feature of North Africa (Toubkal summit at ca. 4167 m). This Alpine intracontinental belt formed during Cenozoic times as a response to

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crustal shortening. The latter is considered either as moderate (Mattauer et al., 1977) or as strong (e.g. Frizon de Lamotte et al., 2000; Morel et al., 2000). Nevertheless, a deep thermal doming related to a lithospheric thinning has also been proposed recently to characterize the shortening as moderate (i.e. 15–20 km) (Teixell et al., 2003; Frizon de Lamotte et al., 2004; Zeyen et al. 2005; Missenard et al., 2006). The bi-vergent High Atlas exhibits horizontal contraction characterized by thrusting associated with strike-slip faulting (e.g. Fraissinet et al., 1988; Froitzeim et al., 1988; Morel et al., 2000, Laville et al., 2004). The MHA exhibits abundant Paleozoic and Precambrian rocks which outcrop continuously along its axis. On its eastern and northern flanks Precambrian and Paleozoic rocks are unconformably overlain by Triassic and Lower to Middle Jurassic formations. The latter formations have unfilled synrift basins that were inverted during the Cenozoic (Beauchamp et al., 1999; Frizon de Lamotte et al., 2000; Piqué et al., 2002; Laville et al., 2004). Compression resulted in: 1) reverse and strike-slip faulting (Proust et al., 1977), 2) inversion of Triassic to Jurassic syn-rift structures, and 3) evaporite-based detachment folding (Choubert and Faure-Muret, 1962; Michard, 1976; Frizon de Lamotte, et al., 2000). To the north, the MHA thrust onto coarse synorogenic deposits of the Neogene intramountane Haouz basin.

The Ourika watershed zone and its sub-basins are crossed by a major Hercynian shear zone: the N70°E-trending Tizi N'Test Fault (Mattauer et al., 1972; Cornée, 1989; Jenny, 1983; Ouanaimi and Petit, 1992) which stretches northeastwards through the MHA from Agadir to the Aït Akim. The TTFZ separates the Hercynian orogenic domain to the north from the undeformed domains to the south (Anti-Atlas). This shear zone was reactivated with transcurrent and reverse displacement during Atlasic orogen (Proust et al., 1977; Froitzeim et al., 1988; Hafid et al., 2006). The Triassic beds, rest unconformably on the Lower Paleozoic beds or on the

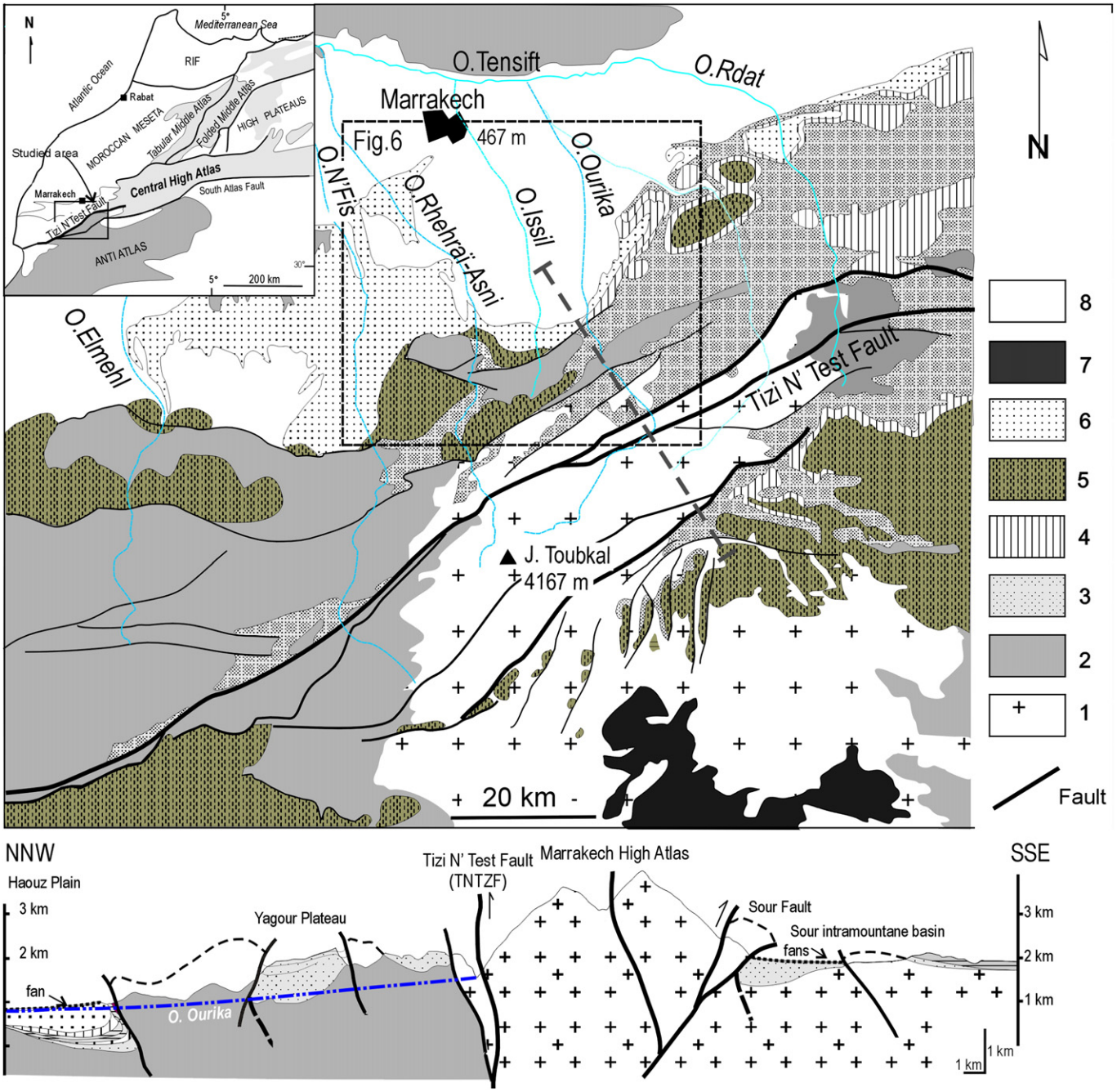

Fig. 1. Simplified geological map of the Marrakech High Atlas and N–S geological cross section. Insert: location of the main structural domains of Morocco. 1: Precambrian, 2: Paleozoic; 3: Trias; 4: Cretaceous; 5: Eocene; 6: Miocene; 7: Mio-Pliocene volcanic rocks; 8: Quaternary.

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