



Research Paper

Chronology of Upper Pleistocene sequences at Sidi Messaoud (wadi Noun, southwestern Morocco) based on ^{14}C , optical and U-series datingNorbert Mercier^{a,*,1}, Christine Hatté^a, Michel Fontugne^a, Jean-Louis Reyss^a, H el ene Valladas^a, Luc Wengler^b, Jean-Philip Brugal^c, Abderrahmane Ouammou^d, Andr e Weisrock^e^a Laboratoire des Sciences du Climat et de l'Environnement, Unit e mixte CNRS-CEA, Avenue de la Terrasse, 91198 Gif-sur-Yvette Cedex, France^b Universit e de Perpignan, Facult e de Lettres et Sciences Humaines, LAPREGEC, 66860 Perpignan, France^c UMR 6636 du CNRS, Maison M diterran enne des Sciences de l'Homme – BP 647, 5 rue du Ch teau de l'Horloge, 13094 Aix-en-Provence, France^d Universit e Ibn Zohr, Facult e des Lettres, D partement de G ographie, B.P. 29 S, Agadir, Maroc^e Universit e Nancy 2, Campus de Lettres et Sciences Humaines, 54000 Nancy, France

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ABSTRACT

The Sidi Messaoud site provides a 40 m thick sedimentary infilling of great importance for the study of environmental changes and landscape evolution during the Upper Pleistocene in the Western Sahara. In this study, chronological results obtained by the ^{14}C , U-series and optical dating techniques are compared. Each individual age, depositional environment and post-deposition history of the various samples are evaluated, in order to explain the methodological reasons for discordances and concordances. Stratigraphic and palaeoenvironmental implications for the last 120 ka history in southwestern Morocco are also inferred: the wadi Noun gorges had been incised before MIS 5, and later, during MIS 3, the valley has been filled in with a mean sedimentation rate of ~ 1 m/ka.

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1. Introduction

The wadi Noun gorges, at the northern border of the Western Sahara, provide a sedimentary infilling of great importance for the study of environmental changes and landscape evolution during the Upper Pleistocene in this area. During the last ten years, two main locations in the gorges have been extensively studied: the Sidi Messaoud site and the Fort Oued Noun site (Fig. 1). The latter, which exhibits a 20 m thick sequence, was formerly investigated by a multidisciplinary team (Weisrock et al., 2006), who showed that the aggradation phase of sediments in this spot occurred during Marine Isotopic Stage (MIS) 5 and 3 (i.e., between ~ 92 and ~ 25 ka), with a maximum of sedimentation (mainly composed of a fine-textured indurated facies) between ~ 50 and ~ 30 ka.

The Sidi Messaoud site is located five kilometers downstream from Fort Oued Noun, at a confluence area. Because of a deep Holocene incision which gives access to more ancient basal deposits, the total exposure reaches 40 m at this location. Moreover, due to steeper adjacent slopes, the lateral colluvial supply was here more abundant during the aggradation phases. Thus, this location is particularly well suited for studying in detail the sedimentation changes in the Western Sahara during the Upper Pleistocene.

For this purpose, we tried to define a detailed chronological framework by applying complementary dating methods: ^{14}C on shells, U-series on travertines, and optical dating on alluvial deposits. Here, we report the results and discuss the various effects affecting the sample age estimates.

2. Geomorphological setting and stratigraphy

2.1. Geomorphological setting

The Sidi Messaoud site ($29^{\circ}5'N$ and $10^{\circ}25'W$) belongs to the southwestern Atlantic border of the Anti-Atlas chain. It lies on the northern dry border of the Sahara where the mean rainfall varies

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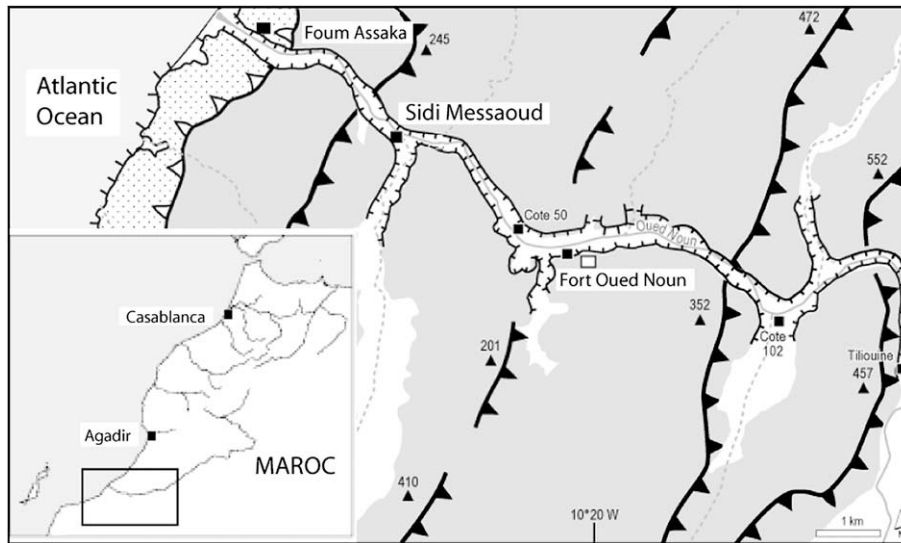


Fig. 1. The wadi Noun gorge and location of Sidi Messaoud site. This area is indicated by the rectangle drawn inset the map.

today from 110 to about 400 mm/year in the whole catchment, but shows great annual variations. Geologically, the area is composed of schist, quartzite and limestone, which extends from an altitude of 327 m at Jebel Tagarlit, but reaches over 1200 m in the higher parts of the catchment.

During the Quaternary, the wadi Noun incised a deep gorge channel through the Anti-Atlas massif and exposed at Sidi Messaoud three main terraces (Oliva, 1977). The oldest one is expected to be the continental equivalent of the so-called Moghrebian (=Plio-Pleistocene) marine terrace which is well developed on the coast at an elevation of 80 m above the present sea-level. The second terrace (the Soltanian terrace) is mainly a silt accumulation resulting from the sedimentation of fluvial, aeolian and lacustrine deposits, in which scarce pebbly channel accumulations are preserved as well as several travertines and carbonaceous materials. The youngest terrace is of Holocene age (Mathieu et al., 2004) and lies close to the present bed of the wadi Noun. This study concerns only the Soltanian terrace (Fig. 2).

Because of its geomorphological setting, between 23 and 63 m above the sea-level, the Soltanian terrace at Sidi Messaoud can be compared with the Fort Oued Noun sequence studied previously (Weisrock et al., 2006). This comparison suggests that this terrace might represent a long aggradational phase, which occurred between MIS 5 and MIS 2. Moreover, remnants of beach deposits were found at the mouth of the wadi Noun, at Fom Assaka (Fig. 1),

at 2 m only above the present sea-level, and travertines were observed in this area near the wadi bed. If these deposits date from MIS 5, they would indicate that the valley had already been incised during MIS 5, by as much as it is today. In this hypothesis, this deep incision would probably have mostly cleaned the valley a few kilometers upstream, and one can suspect that older deposits are preserved at some places along the wadi channel or near the valley slopes. This set of hypotheses was part of the dating challenge.

2.2. Stratigraphy

The wadi Noun infill on the left side of the present channel consists of deposits which can be divided in three main units:

The *Basal unit* (layer 1) is exposed only in the channel of the wadi Noun and its tributary (wadi Bou Smara), and near the left slope of the valley, at 100 m southeast of the main outcrop (Figs. 2 and 3). At the base of the main outcrop (“Wide gully of Sidi Messaoud”), this unit is a pebbly deposit (1a), while in the channel bed of wadi Bou Smara, it consists of a travertine deposit with detrital bottom layers overlain by laminated carbonated stromatolitic layers, that built a dam across the channel (1b). Near the valley slope, this unit is a 10 m thick deposit –section AA’ – with gently sloping beds of angular schist debris and lightly carbonaceous red silts (1c). Stromatolitic laminated travertine deposits of little extend are preserved at their top (1d).

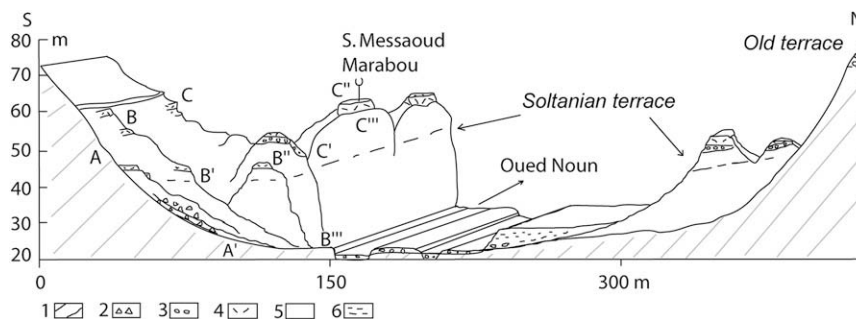


Fig. 2. Schematic cross-section of the wadi Noun valley at Sidi Messaoud, with the location of the different sections shown in Fig. 3. 1: schist, quartzite, limestone; 2: slope deposits; 3: pebbles; 4: travertines; 5: silts; 6: silts and sands.

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