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Investigation of reddening patterns of dune sands — The megabarchans of Al-ghord Lahmar (Khnifiss National Park, South-West of Morocco)

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ABSTRACT

The present paper aims to investigate the geological and environmental parameters controlling the redness of sand at the megabarchans located nearby Khnifiss lagoon (SW of Morocco). Mineralogical investigation either by laboratory or remotely sensed data showed the abundance of a mixed composition of Quartz, Carbonates and mafic minerals with a dominance of Hematite Quartz coated grains. Also, grain size analysis revealed the heterogeneity of the megabarchans sand and the dominance of fine and well to very well sorted sand with a mean grains size of (0.2 mm). Mineralogical species were adequately distributed according to their size and density. We noted the dominance of iron bearing minerals including: Magnetite, Hematite, Ilmenite, Ulvospinel, and Pyroxenes, in the very fine fraction (< 63 μm). Yet, the coarser fractions (> 63) μm knew a dominance of Hematite coated Quartz, Carbonates and Feldspars. These both fractions are carried by wind with almost the same threshold motion, which meant that the size could compensate the density. That explains their deposition in the same environment. The megabarchans migrated over the past 325 years with a rate of 2 m/year. Thus, grains may undergo many turnover cycles until they can be reactivated by wind. Climatic parameters such as precipitations with 164 mm/year, the frequent stormy events that bring a flash flooding, in addition to the high humidity and important fog and dew provide a source of moisture that make the megabarchans a moistened environment encouraging the iron oxidation. Thus, the abundance of a source of iron and a source of moisture, in addition to the stability of the megabarchans, and their water holding capacity remained the effective factors that led to the megabarchans redness.

1. Introduction

Al-Ghord Lahmar are three giant barchans and a complex dune system, which is located at Khnifiss national park in the south-western area of Morocco (Fig. 1; Fig. 2.c, d). These dunes exhibit several features that make them special and unique in the whole area of Tarfaya basin. Indeed, when compared with other existing dunes in the area, they exhibit strongly red colored sand, a huge size, and a particular morphodynamic in addition to their ability to emit a loud sound coming from the avalanche motion. Previous works investigated the strange singing of these megabarchans (Andreotti, 2004; Douady et al., 2006), and their dynamics (Elbelrhiti et al., 2005). However to the best of our knowledge, no study was conducted on their reddening patterns. Since generations, this special red color caught the attention of local population. They believed on a mythical story that attributed the red color in sand, to the blood that drenched it when it was a battlefield between local tribes.

In several studies, color variations were clearly observable on the sand blown over coastal areas. The Namib sand sea example showed a case where the reddening increased with the distance from the coastal area to inland (Walden and White, 1997). Nevertheless, such variations have also been observed for continental sand dunes, in Yerdi region at the South-East of Morocco (Adnani et al., 2016). Sand dunes around Khnifiss lagoon showed a large color variation, ranging from reddish gray sands (10R 5/1) in the beach of Sidi Akhefnir town, in the East and extending West to pale yellow (2.5Y 8/4) around Foum Agoutir, which is the inlet of Khnifiss lagoon. There are transverse dunes around the lagoon, starting from the beaches surrounding Foum Agoutir and extending NE-SW. They are also characterized by pale yellow color (2.5Y 8/4) (Fig. 2.e). Conversely, at nearly 2.5 km towards the SE, we observed three huge barchans extending NE-SW (650 m wide and 40 m high), that are exceptionally composed by reddish yellow sand (7.5YR 6/8). Regarding the composition of their sand, we noticed the

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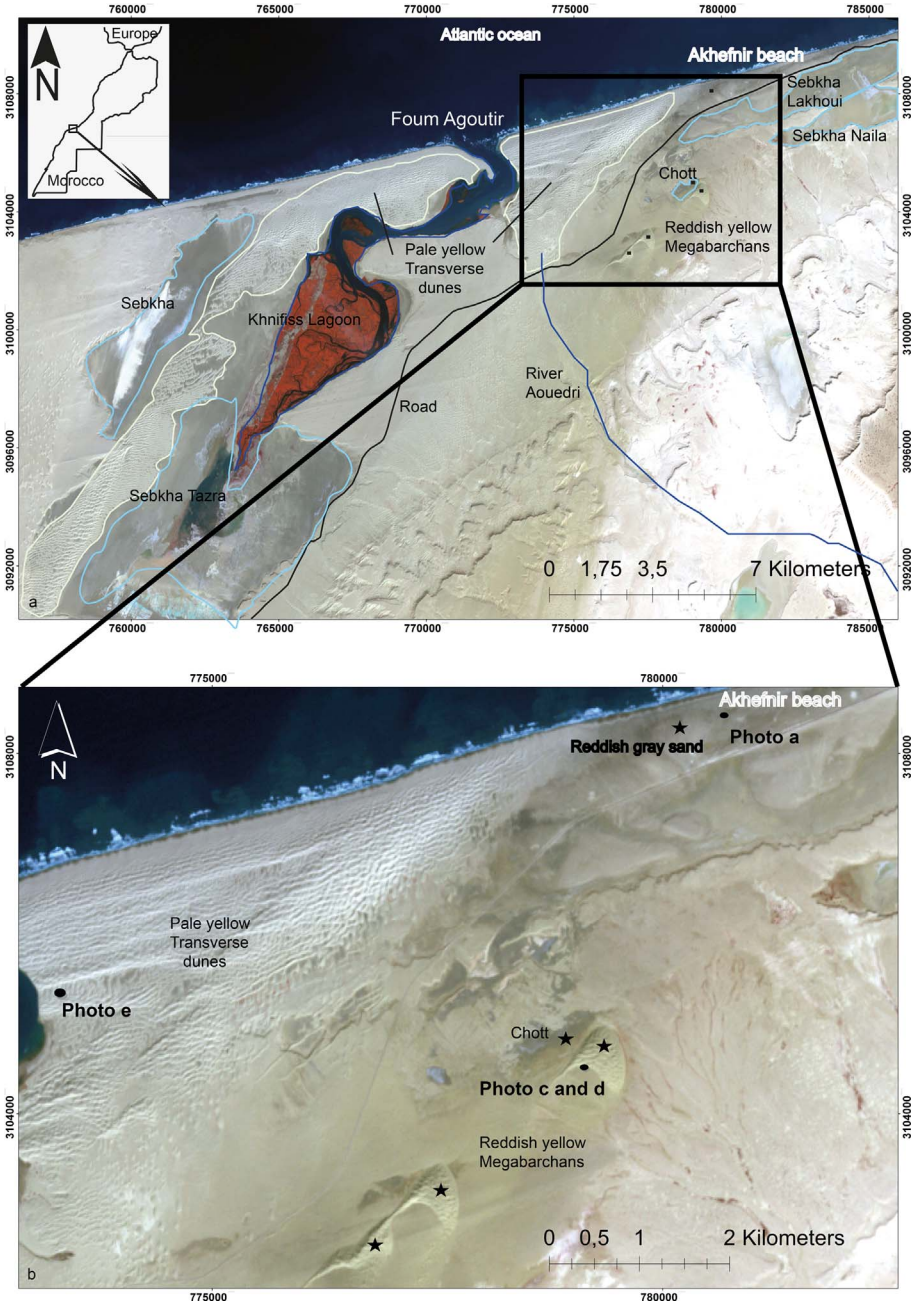

Fig. 1. The study area situation: a) Color composition of ASTER (2016) bands 3, 2, 1 respectively on the R, G, B channels. b) Zoom on the megabarchans field, the natural colors of ASTER image highlight the redness differentiating the megabarchans from dunes in the surrounding area. The stars represent the sampling sites localization.

abundance of opaque grains. These opaque grains were mixed with other grains having different colors, sizes, shapes and mineralogical compositions. Inquiringly, 3.5 km towards the NE, in the beach near Sidi Akhefnir town, we observed an important concentration of such opaque minerals (Fig. 2.a).

According to previous works, the reddish sand color was due to the layer of Hematite (Ferric Iron) covering the Quartz grains (Folk, 1976; Gardner and Pye, 1981), and the red color variation could be explained by the thickness of this Hematite coating (Lancaster, 2013). Therefore, the reddening processes depend primarily on the availability of an iron source (Gardner and Pye, 1981). Also, several other factors led to the development of the red pigment: The sand evidently needs time in addition to favorable oxidizing conditions (warm temperature and moisture) to develop its red color (Norris, 1969; Gardner and Pye, 1981; Lancaster, 1989). Indeed, soil rubification is defined as a pedogenesis stage in which iron is released from primary minerals to form free iron oxides that coat Quartz particles in soils with a thin reddish film (Ben-Dor et al., 2006). Several authors suggested other factors, such as the contribution of dustfall to the increase of sand dunes redness (Folk, 1976; Lancaster, 2013). However, the coating could be removed by abrasion which reduces the redness (Bullard and White, 2005). Generally, as the sand migrates from the coastline, the conditions that increase its redness are favored (Levin et al., 2007). From their work on the great sand sea of Egypt, Besler (2008) proposed two possible origins of redness in dune sands: the in situ rubification related to pedogenesis process in warm climates with alternately dry and humid seasons, and the redness inherited from red deposits after a short transport. Earlier studies of Capot-Rey (1970) stated that the reversed process, which is sand bleaching, occurred in warm environments as soon as the annual precipitation exceeded 150 mm. Later, Levin et al. (2007) reported the example of the whitening process of a dune field with interdunes water ponds in NE Brazil. In fact, the statement of dunes reddening with age is only valid in the case of the interruption of pedogenesis or diagenesis periods (Besler, 2008). As an example, Roskin et al. (2012) found no