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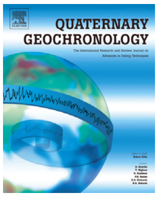

Dating desert pavements – First results from a challenging environmental archive

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ABSTRACT

Desert pavements are widespread landforms of arid environments. They consist of a monolayer of clasts at the surface, associated with an underlying unit of eolian fines. In some situations, buried desert pavements can be observed, which is interpreted as a change in the environmental conditions. Therefore, it is believed that desert pavements represent important paleoenvironmental sediment archives, especially for arid environments, where natural archives of past environments are rare. To better understand the formation process of desert pavements and to enable the paleoenvironmental interpretation of these valuable sediment archives, reliable chronologies are of crucial importance. Thus, OSL dating was applied to samples from well-developed desert pavements in two different study areas, the Cima Volcanic Field, eastern Mojave Desert, USA, and the desert of northeastern Badia, Jordan. To test the suitability of the sediments for OSL dating, the luminescence characteristics of the fine- and coarse-grain quartz fraction are described and compared. Finally, first OSL ages are presented.

1. Introduction

Desert pavements are typical geomorphological features in arid environments (Goudie, 2013). They are composed of a monolayer of clasts at the surface, associated with an underlying unit of eolian fines (sandy silt), which exhibits a several centimeter thick foamy pore structure directly beneath the clasts, the vesicular horizon (Springer, 1958; McFadden et al., 1998; Anderson et al., 2002; Dietze et al., 2012). Desert pavements form by dust trapping, causing vertical accretionary rise above a thickening eolian mantle (Mabutt, 1977; McFadden et al., 1986; Gerson and Amit, 1987). In some situations, the described sediment succession of pavement clasts and eolian mantle is underlain by another sediment unit of equal succession, interpreted as a buried desert pavement (Dietze et al., 2011; Dietze and Kleber, 2012; Dietze et al., 2013). It is believed that changes in the environmental conditions, e. g. variations in precipitation, dust flux or vegetation cover, are responsible for the changes in the rate of desert pavement aggradation or its burial (Dietze et al., 2013). In this sense, the sediment units of desert pavements represent important paleoenvironmental sediment archives, especially for arid environments, where natural archives of past environments are rare.

To better understand the formation process of desert pavements and its boundary conditions (precipitation, dust flux, vegetation etc.) and to enable the paleoenvironmental interpretation of these valuable sediment archives, reliable chronologies are of crucial importance. So far, the age of desert pavements, defined as the beginning of eolian fine accumulation beneath the clasts, were dominantly estimated using relative age indicators such as geomorphological and pedological parameters (Wells et al., 1985). However, Dietze et al. (2011) demonstrate that these relative age indicators are problematic, because there is no direct relationship between the surface properties, soil development and the age of desert pavements. Numerical dating of the clasts of desert pavements using cosmogenic ^{3}He and ^{10}Be surface exposure dating was e. g. applied by Wells et al. (1995) and Matmon et al. (2009), with a focus on dating the beginning of desert pavement formation and investigating their surface stability over time. However, the process of dust trapping and therefore the dating of the eolian fines below the desert pavement can best be dated by luminescence dating techniques (Aitken, 1985). This technique enables the direct dating of sediment deposition and therefore sheds light on the process

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and the paleoenvironmental conditions of desert pavement formation, as well as on its rate of formation.

Even though desert pavements are global phenomena of arid landscapes, there are only a very limited number of studies where luminescence dating was applied to decipher the chronology of these valuable sediment archives. Anderson et al. (2002), Wells et al. (1995) and McFadden et al. (1998) applied thermoluminescence dating (TL) on desert pavements in the Mojave desert, USA, while Matmon et al. (2009) used optically stimulated luminescence dating (OSL) for their investigations in the Negev desert of southern Israel. However, in all of these studies, the dating results are presented, but no details about the luminescence characteristics are given and discussed.

In this study we investigate the suitability of desert pavement eolian fines for OSL dating from two different study areas. From both study areas, the Mojave Desert, USA, and the desert of northeastern Badia, Jordan, fine- and coarse-grain quartz samples were used for OSL measurement and OSL characterization. Finally, first OSL ages from both grain sizes are presented, which lead to a new view on the formation of desert pavements and its environmental boundary conditions.

2. Study area

For this study, samples from two arid landscapes with well-developed desert pavements were used. The first study area is located in the Cima Volcanic Field, eastern Mojave Desert, southwestern USA (Fig. 1). There, one sediment profile (CVF07-002; cf. (Dietze and Kleber, 2012)) on a 560 ± 80 ka old basalt flow (Turrin et al., 1985) was sampled. The profile is situated on a gently inclined slope, at an altitude of ca. 900 m a.s.l., and possible dust sources for desert pavement development are represented by numerous playas situated in the vicinity of the Cima Volcanic Field. Annual precipitation varies between ca. 69 mm in Baker (320 m a.s.l.) and 160 mm in Yucca Grove (1204 m a.s.l.). The same climate stations record annual air temperatures of 21 °C and 14.7 °C, respectively. The precipitation and temperature is mainly controlled by topography and elevation, with dominantly winter precipitation associated with southwestern storm fronts (Koehler et al., 2005). In total, four OSL samples were analyzed from the profile, all taken from the eolian fines below the desert pavement and below the vesicular horizon (Fig. 2). Sample GI70 was taken in 15 cm, sample GI71 in 33 cm, sample GI72 in 53 cm and sample GI73 in 74 cm depth.

The second study area is located in the desert of northeastern Badia, Jordan (Fig. 3). This desert is again characterized by well-developed desert pavements, even though their eolian fines are less thickly developed (ca. 30–80 cm) than the ones from the Mojave Desert (ca. 80–120 cm). In Jordan, three sediment profiles were investigated, with sample GI54 (22 cm), GI55 (35 cm) and GI56 (50 cm) from profile JO13, sample GI57 (30 cm) and GI58 (50 cm) from profile JO14 and finally GI59 (30 cm) from profile JO15. Again, OSL samples were taken from the eolian fines below the desert pavement and below the vesicular horizon (Fig. 4). All investigated profiles are situated on gently inclined slopes, at an altitude of 700 m–850 m a.s.l., and were developed on basaltic lava flows with ages between 0.15 Ma and 14 Ma. Possible dust sources for desert pavement development are the playas in the eastern and southern part of the northeastern Jordan Badia desert, but also long-distance dust from the northeastern African desert regions (Yaalon and Ganor, 1973). Annual precipitation in the northeastern Jordan Badia is about 75 mm, with a mean annual air temperature of ca. 22 °C (Al-Qudah and Abu-Jaber, 2009).

3. OSL sample preparation and measurement procedure

To determine the equivalent dose (D_e), the fine- (4–11 μm) and coarse-grain (90–125 μm) quartz fraction was prepared from sediment samples taken during the night from an iteratively deepened surface patch to minimize vertical sample thickness to 1–2 cm sediment sample. In a first step, the sediment was wet sieved, followed by a treatment with HCl and H_2O_2 to remove carbonates and organics. To gain the coarse-grain fraction, density separation with lithium-heteropolytungstate (2.68–2.62 g/cm^3) was used and afterward the quartz extract was etched in 40% HF for 80 min, to remove the α-irradiated outer layer of the grains and to remove any feldspar contamination. In a final step, the coarse-grain quartz fraction was washed for 30 min in 10% HCl. The fine-grain fraction was separated by settling using Stokes' law. To get pure fine-grain quartz extracts, the polymineral samples were etched in 34% pre-treated H_2SiF_6 for several days (Fuchs et al., 2005). For

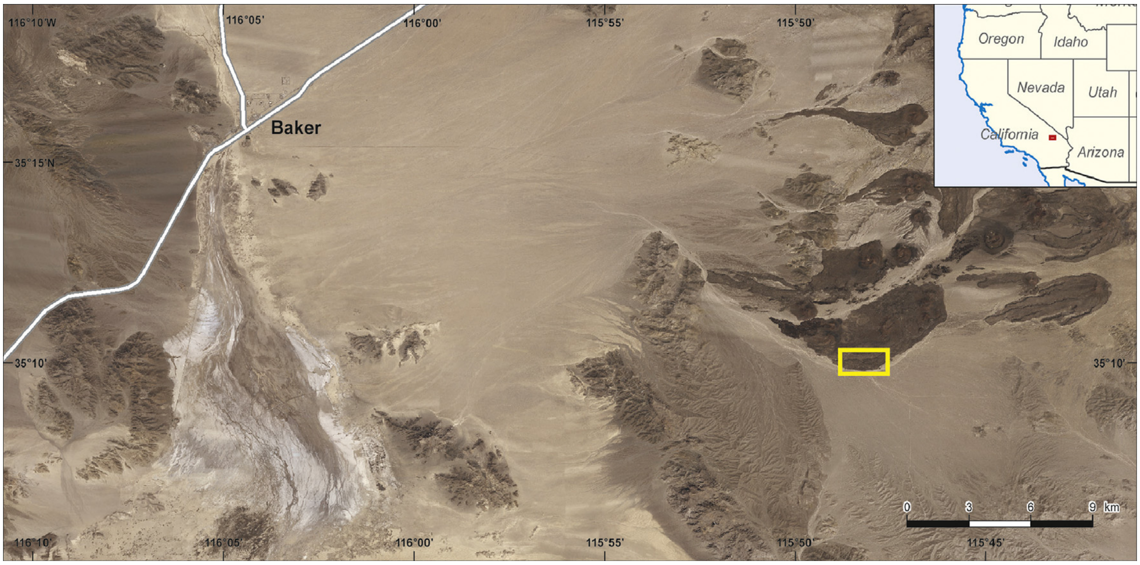

Fig. 1. Study area Cima Volcanic Field (CVF) in the eastern Mojave Desert, southwest USA. The sampling locality is indicated by the yellow frame. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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