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Cover beds older than the mid-pleistocene revolution and the provenance of their eolian components, La Sal Mountains, Utah, USA

Jana Krautz [a, *], Andreas Gärtner [b], Mandy Hofmann [b], Ulf Linnemann [b], Arno Kleber [a]

[a] *Geographisches Institut, Technische Universität Dresden, Helmholtzstr. 10, 01069, Dresden, Germany*

[b] *Senckenberg Naturhistorische Sammlungen Dresden, Museum für Mineralogie und Geologie, Sektion Geochronologie, Königsbrücker Landstraße 159, 01109, Dresden, Germany*

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A B S T R A C T

We used uranium-lead (U-Pb) dating of zircons from a tephra layer deposited in the La Sal Mountains to assign an age of more than c. 1.3 Ma to underlying loess-mixed slope deposits (cover beds) and paleosols developed therein. For the first time, we show that properties of cover beds and soils before the Mid-Pleistocene Revolution were similar to those formed after the revolution. However, the deepest exposed carbonate-enriched horizon is much farther developed than younger ones, indicating that there was a period of enrichment by far exceeding intensities of younger calcic horizons some time before the revolution, possibly in Neogene times. Remarkable differences between age distributions of detrital zircons (DZ) within the cover beds allow reconstructing the regional provenance of mixed eolian matter with high accuracy: we were able to trace particular cover beds back to areas with outcropping Permian and Upper Cretaceous rocks.

1. Introduction

In mountainous environments of the mid-latitudes cover beds are common features and are supposed to be the most abundant surficial materials on slopes of low to intermediate gradient (Kleber, 1997; Kleber et al., 2013). Hence, they are a decisive component of "Earth's critical zone" (Kleber and Terhorst, 2013). Cover beds are defined as deposits formed by processes of unconcentrated dislocation chiefly from upslope materials, which may be mixed with eolian matter. They cover slopes to a large extent, rather than being restricted to drainage ways or local failures. Cover beds typically consist of layers, which are separated by disconformities (Kleber and Terhorst, 2013). In the vicinity of the northern Great Basin, western USA, cover beds typically contain eolian particles (Kleber, 1994).

Cover beds are rarely well dated, but by far the most instances appear to relate to the last glaciation (Hülle and Kleber, 2013). Moreover, in the western USA there is also strong evidence of cover beds that have formed during the termination of the penultimate glaciation (Kleber, 1994). There, discriminating layers of cover beds is made possible by examining soil properties, especially by the overprint of argillic features by later carbonate enrichment (Kleber, 2000). Cover beds may be considered as archives of past environments. As with their age, the duration of the formation of cover beds is an open question, though this would be an important aspect to judge what they may tell about the paleoenvironmental conditions under which they have formed. In this context, it would be helpful to know a minimum age of the cover-bed formation, especially, whether their formation was possible during the much shorter-lasting glaciations before the "mid-Pleistocene revolution" almost 1 Ma ago. Before this revolution each glacial cycle lasted c. 40 ka on average, whereas cycles persisted for c. 100 ka afterwards (Paillard, 2001). However, as yet no evidence of cover beds that old has been reported.

In the La Sal Mountains, Colorado Plateau, southeastern Utah, a cover bed has incorporated a layer of tephra derived from the Jemez Mountains, New Mexico, USA (Kleber, 2013). Kleber (2013) speculated that the tephra layer may have been reworked much later than its primary deposition, so that the encompassing cover bed as well as underlying, older cover beds might be of much younger age than the original tephra. Here we present ages of this tephra using U-Pb series age determinations of zircons. To test whether these determinations allow for assigning minimum ages to the

* Corresponding author.
E-mail address: jana.krautz@tu-dresden.de (J. Krautz).

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underlying cover beds, we also dated detrital zircons (DZ) in these older cover beds to evaluate whether they contain zircons of the same or even younger age than the tephra, i.e., whether there is evidence of reworking of the tephra material or whether the tephra layer may be regarded as being in situ.

2. Materials and methods

2.1. The La Sal Mountains tephra layer

Referred to hereafter as the La Sal Mountains (LSM) tephra layer, the tephra was found in the north-western LSM, Utah, U.S.A. (located 38°34′33″N, 109°17′32″W), at an elevation of 2130 m a.s.l. on a 22° steep slope, exposed by a road cut of the Manti-La Sal circuit (Fig. 1). The tephra was identified by the US Geological Survey, Tephrochronology Laboratory, Menlo Park, CA, via the major-element composition of its glass shards as either the approx. 1.65 Ma old (Spell et al., 1990) Guaje Tephra or the approx. 1.25 Ma old (Phillips et al., 2007) Tsankawi Tephra, both derived from the Jemez Mountains, NM (the geochemical data of the glass-shards are published by Kleber, 2013 and Krautz et al. 2018). In the field and under the microscope, the tephra layer shows only slight indication of weathering; there is no such indication at all in its core. Such preservation is unlikely, if the tephra layer had been as close to the surface, i.e. 90 cm, as it is now since more than 1 Ma. Thus, the question arises whether material originally overlying the LSM tephra layer has been eroded or whether the tephra layer, despite its pure appearance, was reworked considerably after it had been originally deposited and is in a secondary position in this profile.

2.2. Cover beds and paleosols

If the LSM tephra layer, dated at either 1.25 or 1.65 Ma on the basis of its correlation with a Jemez Mountains eruptive, is largely in its primary position of deposition, i.e. in situ, the underlying deposits would predate the mid-Pleistocene revolution. Beneath the LSM tephra layer, the exposure consists of several soil horizons that were formed mainly from loess- and gravel-rich cover beds during various soil-forming episodes (Fig. 1). Various paleosols may be distinguished by means of their compound clay- and carbonate-enriched (argillic and calcic, respectively) soil horizons (Kleber, 2013): the carbonate in these compound horizons is supposed to have accumulated after the argillic properties had been formed, because simultaneous carbonate enrichment and clay illuviation are mutually exclusive in the same horizon. Hence, clay translocation was only possible during or after the carbonate had been depleted (cf. Kleber, 2000 for detailed reasoning). Furthermore, a much warmer soil-temperature regime than the area is experiencing at present would have been needed to form calcic horizons reaching as deep as in this profile, provided the distance of the horizon from the surface was the same as it is at present (cf. McFadden and Tinsley, 1985), let alone materials that might have been eroded off the top of the profile. Both lines of reasoning lead to the interpretation that the parent material of each soil was deposited after the argillic properties in the respective underlying soil had already been formed, which implies that the latter is part of an even older paleosol (cf. Kleber, 2000). Accordingly, the soils in this profile most likely formed during a considerable span of time before the deposit containing the LSM tephra layer arrived.

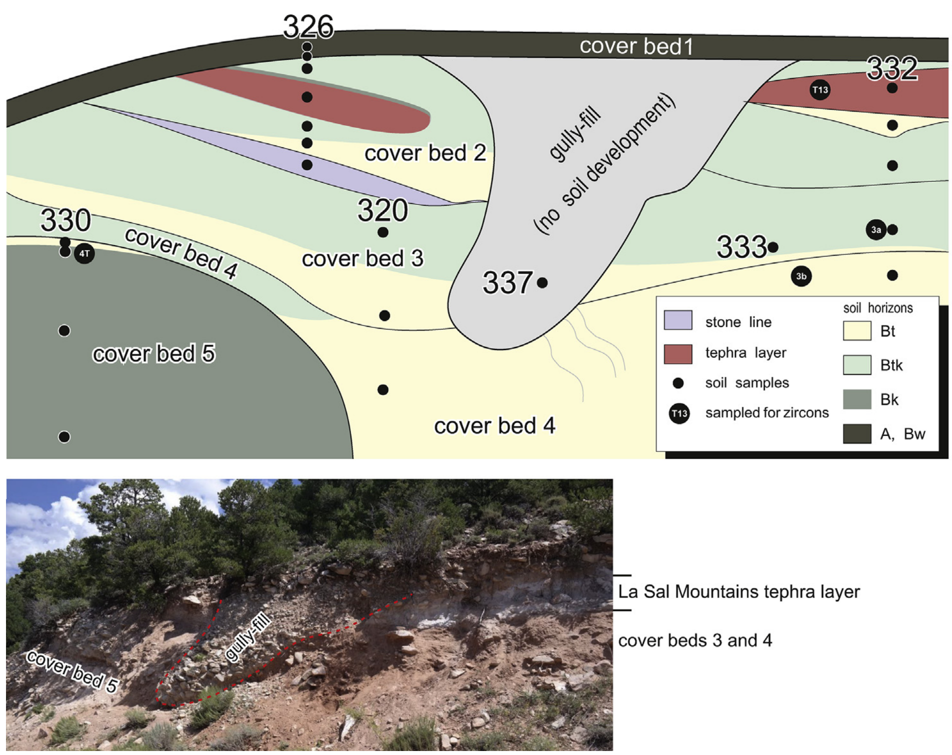

Fig. 1. Top: Sketch of soils and deposits of the exposure under study.
The scale is aproximate. There is no visible soil development in the gully fill and in the tephra layer in the right part of the exposure, whereas there is some carbonate and clay enrichment in the left occurrence of the tephra layer. The samples taken for U-Pb dating of zircons are 2013 LSM-T (T13) and 2014 LSM-3a, -3b, and -4T within cover beds 3, 4, and 5, respectively. The numbers at soil samples refer to the start of the particular columns in Table 1.
Bottom: The exposure under study. Photograph by Florian Schneider (on student field trip, Aug. 18, 2015).