Enhanced Saharan dust input to the Levant during Heinrich stadials

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The history of dust transport to the Levant during the last glacial period is reconstructed using the isotope ratios of Pb, Sr, Nd, and Hf in sediments of Lake Lisan, the last glacial Dead Sea. Exposed marginal sections of the Lisan Formation were sampled near Masada, the Perazim Valley and from a core drilled at the deep floor of the modern lake. Bulk samples and size fractions display unique isotopic fingerprints: the finest detritus fraction (<5 μm) displays higher 87Sr/86Sr and lower εNd values (0.710–0.713 and −7.0 to −9.8, respectively) relative to the coarser fractions (5–20 μm and <20 μm; 0.708–0.710 and −3.4 to −8.3) and the bulk detritus samples (0.709–0.711 and −6 to −7.5). Similarly, the 206Pb/204Pb, 207Pb/204Pb and 208Pb/204Pb ratios (18.26-19.02, 15.634-15.68, and 38.25-38.82, respectively) are systematically higher in the finest detritus fraction relative to corresponding coarser fractions and bulk samples. The 87Sr/86Sr and εNd values of the finest fraction correspond with those of atmospheric dust originating from the Sahara Desert, while those of the coarse fractions are similar to loess deposits exposed in the Sinai and Negev Deserts. Pronounced excursions in the Sr-Nd-Pb isotope ratios toward more Sahara-like values coincide with the Heinrich (H) stadials 6, 5 and 1, reflecting significant increases in Saharan dust fluxes during regionally arid intervals, reflected by sharp lake level drops. Moreover, during H6 the dust came from different Saharan sources than during H1 and H5. While the relatively wet glacial climate in the Levant suppressed the transport of dust to the lake watershed, short-term hyper-arid spells during H-stadial intervals were accompanied by enhanced supply of fine Sahara dust to this region.

1. Introduction

1.1. Overview

The Sahara-Arabian desert belt is the largest and most active dust source in the world, and is the primary dust contributor to the Mediterranean and Middle East (e.g., Jickells et al., 2005; Mahowald et al., 2009; Prospero et al., 2002; and references therein), with nearly half a billion tons exported annually (Schutz et al., 1981). Sahara dust fluxes can be influenced by changes in precipitation at the source areas, especially droughts, which lead to reduced vegetation, allowing for increased wind deflation of soils, and ephemeral stream and lake deposits (Prospero and Nees, 1977). Accordingly, the size and location of the desert belt changed on glacial-interglacial timescales (e.g., Gasse, 2000) which was reflected by changes in the production, transport, and deposition of the fine-grain particles that comprise the desert dust. Climate conditions in the potential sink areas could also affect the airborne particle loads. Thus, characterizing the mineralogical, chemical and isotope properties of dust in various geological archives (e.g., lake sediments, deep sea cores, speleothems, ice cores) along with careful consideration of dust mobilization patterns and deposition mechanisms, and their effect on the interpretation of past dust fluxes, can provide important insights into past wind patterns and its relation to regional and global climate patterns.

Overwhelmingly, studies of past dust patterns have focused on bulk or carbonate-leached samples. Although increased attention has been given in recent years to distinguishing between the compositions of different grain size populations (e.g., Grousset et al., 1992; Galiero, 2007; Meyer et al., 2011; Aarons et al., 2013, 2016; Blakowski et al., 2016; Gili et al., 2016, 2017), such studies...
are still limited. This inhibits the ability to distinguish between the geological provenance of two types of dust sources (Fig. 1): (1) far travelled atmospheric dust ("suspended dust") - high-level dust clouds traveling over significant distances of thousands of kilometers, where the deposition of fine particles (<20 μm) is the result of descending air (dry deposition) or rainfall (wet deposition), and (2) dust deposited relatively close to its source ("settled dust") - low level (up to ca. 3 km elevation) dust clouds associated with shorter transport distances, coarser grain sizes, and deposited as dry fallout (Pye and Zhou, 1989). Because each transport mode is controlled by different processes, and their sources are likely different, it is important to distinguish between their histories.

The Dead Sea, a hypersaline terminal lake located in the morphotectonic depression of the Dead Sea basin (DSB), has a large watershed (~40,000 km²) that extends between the Sahara-Arabian deserts and the sub-tropical Mediterranean climate zone (Fig. 2). During the Quaternary, changing water volumes of the DSB lakes were closely coupled with global and regional climate conditions (e.g., Bartov et al., 2003; Haase-Schramm et al., 2004; Prasad et al., 2004; Stein, 2001; Torfstein et al., 2013b). In particular, the waters of the last glacial Lake Lisan filled the basin and its northward extension (the Jordan Valley), reaching an elevation of up to 160 m below sea level (mbsl), approximately 250 m higher than typical water levels during the Holocene (~400 mbsl). These lake level variations have been interpreted to reflect wetter and drier, glacial and Holocene conditions, respectively, in the lake’s watershed.

The Dead Sea lacustrine system is a sink for airborne material from the Sahara-Arabia desert belt, and therefore, the fine-detritus fraction of the lacustrine deposits is a potential archive of past dust fluxes, its changing composition as well as the sources and routes of transport to the Levant over time (Haliva-Cohen et al., 2012). This information allows reconstruction of the atmospheric conditions that prevailed in this region during the late Quaternary. The exposed bedrocks in the Dead Sea watershed are primarily carbonate rocks (limestones and dolomites), with some additional outcrops of Pliocene-Pleistocene basalts in the Galilee and Golan Heights, and sandstones of different ages in the southeast part of the basin. Granitoid outcrops of the late Proterozoic Arabian-Nubian shield (ANS) are exposed along the southeastern margins of the watershed. Previous studies have shown that the fine siliciclastic detritus (termed hereafter “fine detritus”) comprises primarily remobilized dust derived from sources outside the basin, mainly from the Sahara and Arabian deserts (Frumkin and Stein, 2004; Haliva-Cohen et al., 2012). In turn, this fine detritus has been used to trace dust sources and transport routes to the Dead Sea watershed and its vicinity (e.g., Frumkin and Stein, 2004; Stein et al., 2007; Palchan et al., 2013, 2018; Ben Israel et al., 2015).

The chemical and isotopic compositions of sediments on earth’s surface provide valuable constraints on their provenance, including the source rock composition and age, potential source locations,
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