Predicting desert loess distribution using remote sensing and GIS techniques

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Summary

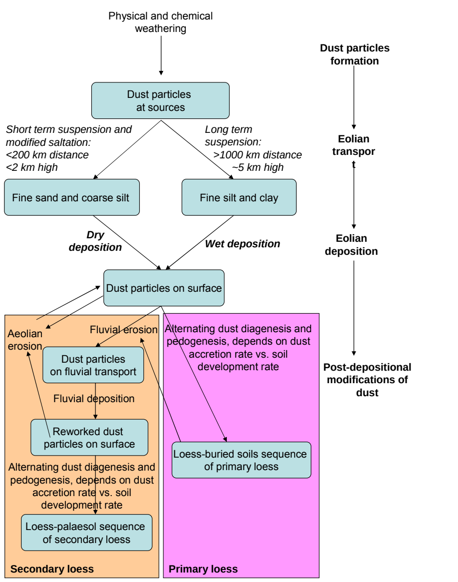
This is a work in progress. Quaternary loess sequences and their buried soils are the products of varying climatic and environmental conditions and usually span intervals >>10³ years long. They are ubiquitous surficial deposits at the Middle East and North Africa desert margins. Interpreting such sequences involves integration of climate, dust availability, deposition and accretion processes. Yet, these processes and their environmental requirements are poorly understood, particularly in desert loess. Most desert loess sequences are mixtures of eolian (primary) and fluvial (secondary) loess and studies usually focused on thick fluvially reworked loess sequences, which complicate extractions of paleoenvironmental information or generalizing on their properties. This is due to non-uniform accumulation process under varying eolian, fluvial, and erosion processes. To overcome this complexity we first identified primary aeolian loess sequences in the Negev and focus our study on the diagenesis and pedogenesis that turn dust into primary loess and control their sedimentologic properties and accumulation and therefore their mechanical properties. This is the first process involved in generating loess sequences and surprisingly the least studied in deserts. Understanding the governing processes will enable us to contribute new data to the reconstruction of the Negev paleoenvironments, dust storms, and other regional climatic conditions that prevailed during the Late Pleistocene.

First, we used spectral field measurements to distinguish and map primary loess on remotely sensed images (Landsat and ASTER) throughout the Negev. The loess spectrum is controlled mainly by a deep Al-OH absorption feature, due to its high clay content. Primary loess was detected on most of the central Negev highland, mountain tops and plateaus, and in several areas in Jordan. The southern and eastern extents of the primary loess in the Negev and Jordan, respectively, follow the 80-100 mm/yr isohyets and therefore they follow regional rainfall distribution controlled by the Mediterranean. Initial studies of primary loess and buried soils reveal that pedogenesis impacted and probably enhanced the accumulation of the entire thickness (0.5-5 m) identified; i.e. there is no original dust without pedogenesis during dust deposition and accumulation. However, only few buried soil horizons are morphologically distinctive. The spatial distribution of the loess indicates a western local source for the majority of dust, such as the expose shelf of northern Sinai during the LGM, in association with the southeastern corner of the Mediterranean and the sharp north-south rainfall gradient.

The Motivation

Loess, is a common sediment composed of eolian dust (silt and clay). It covers ~10% of the terrestrial area of the world, and it is especially abundant in the desert margins. When undisturbed, the loess surface is covered with physical and/or biological crusts, which prevents dust emission. Yet, when disturbed, loess surface are potentially large dust emission areas. Thus, mapping the loess distribution is critical for dust hazard.

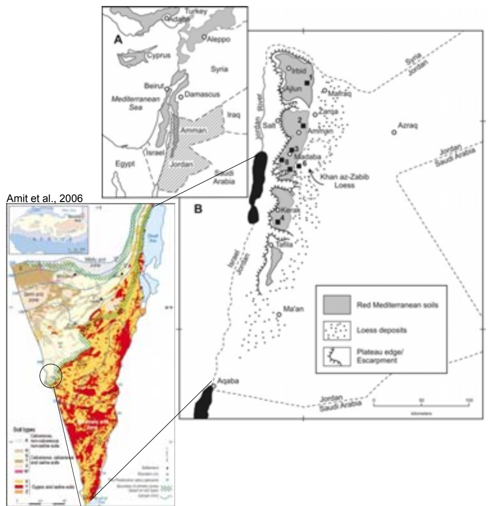
Distinguishing between eolian, primary loess and fluvial, secondary loess is of great importance in mapping loess and a test to our remote sensing abilities in addition to reconstruction of past dust transport, deposition and accretion processes (see below). Deciphering these processes is essential for knowledge-based geologic mapping and determining current dust hazard.



Loess distribution in Israel and Jordan

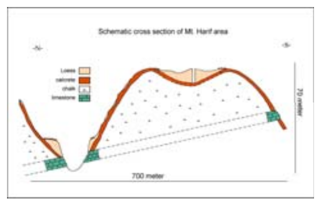
The loess in the Negev desert was associated with semi-arid to arid conditions of mean annual rainfall of 100-300 mm (Yaalon and Dan, 1974; Dan et al., 1976) (Negev soil map below). The dust accretion rate and hence the loess thickness are supposed to increase from zero to maximum with rainfall increase from 100 mm/yr to 250 mm/yr (e.g., Pye and Tsoar, 1987). The loess in Jordan was generally mapped by Cordova et al. (2005) (B below). The authors did not attribute the loess distribution to any climatic regimes.

Amit et al., 2006

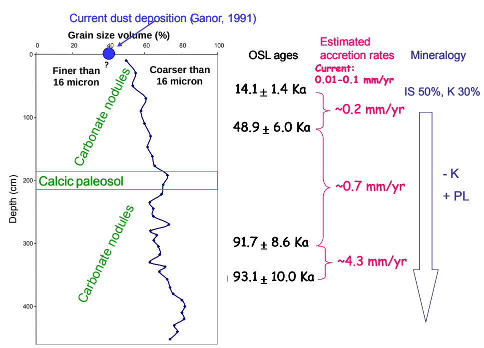


Mt. Harif eolian loess sequence in the central Negev

The 5 m thick loess sequence in Mt. Harif was chosen as a key site. The sequence is located in a small depression on top of a mountain summit without any contributing area, and thus it is a trap of pure eolian loess. In the adjacent valleys, fluvial loess terraces are abundant.

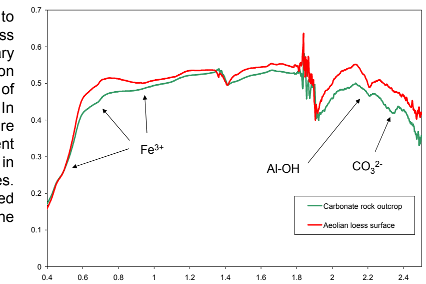


The grain size distribution of Mt. Harif topmost loess is almost identical to current suspended eolian dust in the Negev. The lower sequence is finer. The clay minerals are mainly illite-smectite and kaolinite with increasing palygorskyte content towards the lower part. Our preliminary results indicate that this sequence was accreted almost continuously between 100-14 ka (OSL ages) with only few breaks, with decreasing rate towards top of sequence.



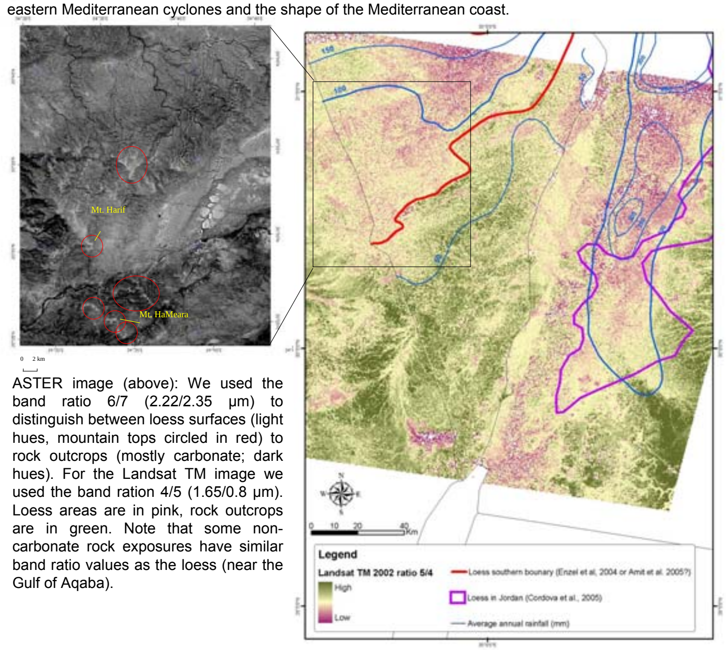
The spectral signature of the loess

We used spectral field measurements to study the spectral signature of different loess surfaces in the Negev desert. The primary eolian loess, has strong Al-OH absorption feature at 2.22 µm, due to the large portion of clay minerals in the loess (~30%?). In addition, the primary loess has ferric feature around 0.9 µm. These features are absent from most of the common rock outcrops in the Negev, which are mainly carbonates. Furthermore, carbonates exhibit well defined feature at 2.33 µm, which is not evident in the loess spectrum.



Remote sensing mapping of the loess distribution

We used the abovementioned spectral differences to map the distribution of loess in arid Israel and Jordan using the ASTER and Landsat TM sensors. Primary loess was detected on most of the central Negev highland mountain tops and plateaus, and in several areas in Jordan. In a series of field sessions we checked these sites in the Negev and verified the existence of primary loess. The southern (in the Negev) and eastern (in Jordan) boundaries of the primary loess accumulation closely follow the present-day 80-100 mm/yr isohyets and are clearly associated with annual/winter rainfall distribution. This distribution is controlled by eastern Mediterranean cyclones and the shape of the Mediterranean coast.



ASTER image (above): We used the band ratio 6/7 (2.22/2.35 µm) to distinguish between loess surfaces (light hues, mountain tops circled in red) to rock outcrops (mostly carbonate; dark hues). For the Landsat TM image we used the band ration 4/5 (1.65/0.8 µm). Loess areas are in pink, rock outcrops are in green. Note that some non-carbonate rock exposures have similar band ratio values as the loess (near the Gulf of Aqaba).

Sponsors

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