Earth-Science Reviews 154 (2016) 247–278

Contents lists available at ScienceDirect

Earth-Science Reviews

journal homepage: www.elsevier.com/locate/earscirev

Invited review

The physics of wind-blown loess: Implications for grain size proxy interpretations in Quaternary paleoclimate studies

Gábor Újvári [a,b,*], Jasper F. Kok [c], György Varga [d], János Kovács [e,f]

[a] Institute for Geological and Geochemical Research, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, H-1112 Budapest, Budaörsi u. 45., Hungary
[b] Geodetic and Geophysical Institute, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, H-9400 Sopron, Csatkai E. u. 6-8., Hungary
[c] Department of Atmospheric and Oceanic Sciences, University of California, 405 Hilgard Ave, Los Angeles, 90095, CA, USA
[d] Geographical Institute, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, H-1112 Budapest, Budaörsi út 45., Hungary
[e] Department of Geology and Meteorology, University of Pécs, H-7624 Pécs, Ifjúság u. 6., Hungary
[f] Environmental Analytical and Geoanalytical Laboratory, Szentágothai Research Centre, University of Pécs, H-7624 Pécs, Ifjúság u. 20., Hungary

ARTICLE INFO

Article history:
Received 21 August 2015
Received in revised form 14 January 2016
Accepted 19 January 2016
Available online 21 January 2016

Keywords:
Loess
Grain size proxy
Quartz
Wind
Aeolian dynamics
Quaternary

ABSTRACT

Loess deposits are recorders of aeolian activity during past glaciations. Since the size distribution of loess deposits depends on distance to the dust source, and environmental conditions at the source, during transport, and at deposition, loess particle size distributions and derived statistical measures are widely used proxies in Quaternary paleoenvironmental studies. However, the interpretation of these proxies often only considers dust transport processes. To move beyond such overly simplistic proxy interpretations, and toward proxy interpretations that consider the range of environmental processes that determine loess particle size distribution variations we provide a comprehensive review on the physics of dust particle mobilization and deposition. Furthermore, using high-resolution bulk loess and quartz grain size datasets from a last glacial/interglacial sequence, we show that, because grain size distributions are affected by multiple, often stochastic processes, changes in these distributions over time allow multiple interpretations for the driving processes. Consequently, simplistic interpretations of proxy variations in terms of only one factor (e.g. wind speed) are likely to be inaccurate. Nonetheless using loess proxies to understand temporal changes in the dust cycle and environmental parameters requires (i) a careful site selection, to minimize the effects of topography and source distance, and (ii) the joint use of bulk and quartz grain size proxies, together with high resolution mass accumulation rate calculations if possible.

Contents

* Corresponding author.
E-mail address: ujvari.gabor@csfk.mta.hu (G. Újvári).

http://dx.doi.org/10.1016/j.earscirev.2016.01.006
0012-8252/

Abbreviations

Appearing in the main text

a — constant in mean charge calculations for raindrops and particles
A_2 — coefficient including factors like particle shape, sorting, packing and bed roughness
A_B — dimensionless threshold friction velocity (Bagnold, 1941)
A_c — the contact area between adjacent grains
A_{Co1} — model parameter associated aerodynamic forces (Cornelis et al., 2004a,b) ($N\ m^{-1}$)
A_{Co2} — model parameter associated inter-particle forces (Cornelis et al., 2004a,b) ($N\ m^{-1}$)
A_{Co3} — geometry factor (Cornelis et al., 2004a) ($N^{-1}\ m^{-1}$)
A_N — dimensionless threshold friction velocity (Shao and Lu, 2000)
b_r — width of an individual roughness element (m)
c_a — heat capacity of air ($m^2\ s^{-2}\ K^{-1}$/$J\ kg^{-1}\ K^{-1}$)
C_1 — coefficient in the Ferguson and Church (2004) model, a constant for laminar settling for $Re_{pt} < 1$
C_2 — coefficient in the Ferguson and Church (2004) model, a constant C_d for $Re_{pt} > 10^3$
C_B — constant for the saltation mass flux model of Bagnold (1941)
C_c — Cunningham slip correction factor
C_d — drag coefficient
C_{DK} — parameter for the saltation mass flux model of Kok et al. (2012)
C_K — constant for the saltation mass flux model of Kawamura (1951)
C_p — local concentration of depositing particles ($g\ m^{-3}$)
C_R — roughness element drag coefficient
C_S — surface drag coefficient
d — zero plane displacement height (m)
D_B — Brownian diffusivity of particles ($m^2\ s^{-1}$)
D_p — particle diameter (m)
D_r — typical roughness element size (Nikuradse roughness)
D_{rd} — raindrop diameter (m)
$D_{rd\text{-}r}$ — representative raindrop diameter (m)
D_w — water vapour diffusivity in air ($m^2\ s^{-1}$)
E_B — collection efficiency from Brownian diffusion
E_{Bw} — collection/collision efficiency from Brownian diffusion in below-cloud scavenging
E_{DPw} — collection/collision efficiency due to diffusiophoresis in below-cloud scavenging
E_{ESw} — electrostatic collection/collision efficiency in below-cloud scavenging
E_{IM} — collection efficiency from impaction
E_{Imw} — collection/collision efficiency from inertial impaction in below-cloud scavenging
E_{IN} — collection efficiency from interception
E_{Inw} — collection/collision efficiency from interception in below-cloud scavenging
EM — end member
$EMMA$ — end member modeling algorithm
E_{TPw} — collection/collision efficiency due to thermophoresis in below-cloud scavenging
F_d — dust emission rate/vertical dust flux of airborne dust ($\mu g\ m^{-2}\ s^{-1}$)
$F_{d,a}$ — dust emission rate due to direct aerodynamic lifting ($\mu g\ m^{-2}\ s^{-1}$)
$F_{d,d}$ — dust emission rate due to disaggregation/auto-abrasion ($\mu g\ m^{-2}\ s^{-1}$)
$F_{d,s}$ — dust emission rate due to saltation bombardment/sandblasting ($\mu g\ m^{-2}\ s^{-1}$)
F_{dep} — dry deposition flux at a reference height z_r ($g\ m^{-2}\ s^{-1}$)
F_D — aerodynamic drag force (N)
F_G — gravity force (N)
F_C — inter-particle cohesive force (N)
F_L — aerodynamic lift force (N)
g — acceleration due to gravity ($m\ s^{-2}$)
GS — grain size
GSI — grain size index, the ratio of 20–50 μm/<20 μm fractions
h_r — height of a roughness element (m)
J — rainfall intensity ($mm\ h^{-1}$)
k_a — thermal conductivity of air ($J\ m^{-1}\ s^{-1}\ K^{-1}$/$W\ m^{-1}\ K^{-1}$)
k_p — thermal conductivity of particle ($J\ m^{-1}\ s^{-1}\ K^{-1}$/$W\ m^{-1}\ K^{-1}$)
k_S — empirical coefficient in the Shao (2001) model
k — Boltzmann constant ($1.3806488 \times 10^{-23}\ J\ K^{-1}$/$m^2\ kg\ s^{-2}\ K^{-1}$)
K — eddy (or turbulent) viscosity
K_{ES} — constant in calculation of the electrostatic collection efficiency
Kn — Knudsen number
LGM — Last Glacial Maximum
m — surface shear stress inhomogeneity parameter
M_a — molecular weight of air ($kg\ kmol^{-1}$)
MAR — mass accumulation rate
M_d — median (D_{50}) grain size (μm)
MIS — Marine Isotope Stage
M_r — modulus of rupture (Pa)
M_s — mean grain size (μm)
MS — magnetic susceptibility
M_w — molecular weight of water vapor ($kg\ kmol^{-1}$)
n_r — number of roughness elements
n_S — empirical coefficient in the Shao (2001) model
$N(D_p)$ — particle number concentration with a diameter between D_p and $D_p + dD_p$
$N(D_p)_t$ — particle number concentration at time t with a diameter between D_p and $D_p + dD_p$
$N(D_p)_0$ — initial number concentration of particles with a diameter between D_p and $D_p + dD_p$
$N(D_{rd})$ — raindrop number size distribution
$N(D_{rd\text{-}r})$ — number concentration of representative raindrop
p_a^0 — vapour pressure of water at temperature T_a (Pa)
p_s^0 — vapour pressure of water at temperature T_s (Pa)
$p_s(D_p)$ — soil/sediment size distribution
$p_f(D_p)$ — fully-disturbed particle size distribution of the parent soil
$p_m(D_p)$ — minimally-disturbed particle size distribution of the parent soil