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Loess Letter is the newsletter of the Loess Commission of the International Union for Quaternary Research (INQUA). It is published by the Geography Department, Leicester University, Leicester LE1 7RH, England, and appears twice a year - normally in April and October, although publication dates may be adjusted to coincide with major loess events. Brief research papers are published, also reviews of recent loess articles, and news items and announcements. Inquiries about the work of the INQUA Loess Commission can be addressed to the President: Professor Marton Pecsi, Geographical Research Institute, Hungarian Academy of Sciences, H-1388 Budapest, Nepkoztarsasag utja 62, P.O.B. 64, Hungary.

LL17 is the first of two special issues to mark the occasion of the 12th INQUA Congress, held in Ottawa, Canada, 31 July-9 August 1987. Loess Letter has also published twelve supplements to celebrate this major Quaternary event. These will be available at Ottawa, or may be obtained from the LL editorial office in Leicester. The major part of LL17 is given over to excerpts from H. J. Mücher's thesis: 'Aspects of Loess and Loess-derived Slope Deposits: an Experimental and Micromorphological Approach'. This was published by CIP-Gegevens Koninklijke Bibliotheek, Den Haag in 1986.

The early part of the Mücher book (in particular Chapter one) is a timely review of recent loess literature, and parts of this, together with the associated bibliography, make an ideal Loess Letter contribution to the surveys and discussions of loess which will take place at the Ottawa INQUA loess symposia. We also publish in LL17 a short paper by Professor Dan Yaalon on desert loess. Readers of LL who are interested in desert loess will also want to read:

Tsoar, H. & Pye, K. 1987. Dust transport and the question of desert loess formation. Sedimentology 34, 139-153. Dr.Tsoar's contact address is Geography Department, Ben-Gurion University of the Negev, Be'er Sheva, Israel.

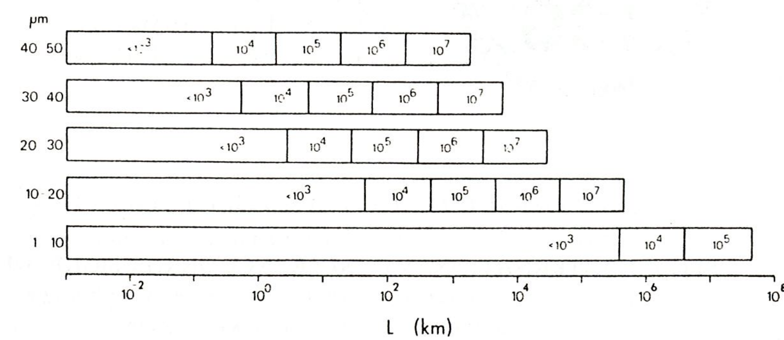

Fig. 3. The maximum distances likely to be travelled by different size classes of quartz spheres when $\bar{U} = 15$ m s^{-1} and ε varies from 10^3-10^7 cm^2 s^{-1}.

Boardman, J. & Hazelden, J. 1986. Examples of erosion on brickearth soils in east Kent. Soil Use and Management 2, 105-108.

Abstract. High rates of erosion are reported from three sites on brickearth (loess) soils in east Kent. Problems are acute where soils are used for intensive production of vegetables and salad crops. Erosion appears to be the result of structural instability, lack of crop cover for much of the year, and certain management practices, such as ridging the soil for the crop. In the autumn of 1984, about 120 tonnes of soil was lost from rills in a field of onions: an erosion rate of about $15tha^{-1}$. A large field under winter cereals also eroded and this resulted in damage to property. Conservation techniques are recommended.

For more details of these erosion studies contact: Dr. J. Boardman, Humanities Department, Brighton Polytechnic, Falmer, Brighton, East Sussex BN1 9PH, England.

East Asian Tertiary/Quaternary Newsletter No.6

This newsletter is published by the Centre of Asian Studies of the University of Hong Kong, Pokfulam Road, Hong Kong. No.6 has some items of loess interest - including Thermoluminescence dating of loess sections; Quaternary stratigraphy of the Himalaya; Quaternary research in Australia and New Zealand; Geology of China; International symposium on loess research; Loess and the Environment; Loess Letter, etc.

SECOND INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY
ICG
FRANKFURT 1989

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"GEOMORPHOLOGY AND GEOECOLOGY"
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Deuxième Conférence Internationale de Géomorphologie
September 3–9, 1989 Frankfurt/Main

АКАДЕМИЯ НАУК СССР
ГОССТРОЙ СССР
ПРОИЗВОДСТВЕННЫЙ И НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ ПО ИНЖЕНЕРНЫМ ИЗЫСКАНИЯМ В СТРОИТЕЛЬСТВЕ

Н. И. КРИГЕР

ЛЁСС

Формирование просадочных свойств

Ответственный редактор
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М.П. ЛЫСЕНКО

New from 'Nauka'

МОСКВА
"НАУКА"
1986

ПРЕДИСЛОВИЕ

Проблема лёсса (т.е. проблема происхождения лёсса и его свойств) прошла почти через всю историю геологии, породила множество научных концепций и споров, приобрела большое научное и практическое значение. Лёсс изучается различными науками о Земле (геология, минералогия, геохимия, почвоведение, физическая география, геоморфология, климатология, палеогеография, биогеография и т.д.) и прикладными дисциплинами (инженерная геология, механика грунтов, агрономия и т.д.).

Данная работа в сжатом виде содержит итог исследований автора о лёссе, его происхождении, литологии, геохимии и просадочных свойствах. Эти исследования были начаты около 50 лет назад, но наиболее интенсивно ведутся с 1950 г. Они проводились в разных районах Средней Азии, Южного и Центрального Казахстана, Рудного Алтая, Предкавказья, Русской равнины (бассейн Оки, Среднее Поволжье, Калмыкия, некоторые районы Украины, Белоруссии и Молдавии).

Основным итогом указанных исследований считают разработку концепции, в которой состав и просадочные свойства лёсса (и других геологических образований) рассматриваются в связи с окружающей географической средой и техногенезом в свете различных научных дисциплин. Это нашло отражение в формировании особых направлений исследований, названных литоэкологией и сейсмическим грунтоведением (сейсмической литологией).

Необходимо дать несколько определений, которые в следующих главах будут уточняться.

Под географической средой (природной средой, системой внешних физических полей) здесь понимается система, объединяющая верхнюю часть литосферы (зону гипергенеза), гидросферу и нижнюю часть атмосферы (тропосферу). В данной работе географическая среда рассматривается прежде всего как среда образования и существования лёсса. Характеристики рельефа, климата, почв, геологического строения, гидрологических условий, геофизических полей и техногенеза являются параметрами географической среды. Строительство и другие проявления техногенеза на застраиваемых и застроенных площадках используются автором как особый вид эксперимента по изучению изменения пород под влиянием окружающей среды [105].

Просадкой называется уплотнение породы в напряженном состоянии при увлажнении. К.И. Лисицын, А.М. Дранников, а также

Э. М. Мурзаев, В. В. Обручев,
Г. Е. Рябухин

Владимир Афанасьевич ОБРУЧЕВ

1863—1956

Издание 2-е,
переработанное, дополненное

Ответственный редактор
член-корреспондент АН СССР
Н. А. ФЛОРЕНСОВ

New from 'Nauka'

МОСКВА
«НАУКА»
1986

ББК 26.3
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УДК 550.9 В. А. Обручев

Рецензенты:

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Мурзаев Э. М., Обручев В. В., Рябухин Г. Е.

М 91 Владимир Афанасьевич Обручев: 1863—1956. — 2-е изд. перераб., доп. — М.: Наука, 1986. — 208 с., ил. — (Научно-биографическая литература). 80 к. 35 700 экз.

Книга посвящена жизни и творчеству неутомимого путешественника, выдающегося советского ученого, Героя Социалистического Труда, академика В. А. Обручева. В ней рассказывается о его научных исследованиях, литературном творчестве и общественно-педагогической деятельности. По сравнению с первым изданием этой книги в 1959 г. авторы, близко знавшие В. А. Обручева, внесли значительные дополнения по материалам последних публикаций об ученом и в соответствии с современными научными представлениями.

Для широкого круга читателей, интересующихся развитием науки.

М $\frac{1402000000\text{-}021}{054\ (02)\text{-}86}$ 28-86 II П — ББК 26.3

Эдуард Макарович Мурзаев, Владимир Владимирович Обручев, Георгий Евгеньевич Рябухин

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1863—1956

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Жажда предвидения, отгадки, обобщения найденного при помощи искусства — это черта вечной молодости Владимира Афанасьевича Обручева.

М. Шагинян

Юность

Семья и родные

Один из далеких предков Владимира Афанасьевича по преданию происходил из поморов. Он был бочаром — мастерил обручи для бочек, в которых возили соленую рыбу из Архангельска в Москву. Отсюда, очевидно, и произошла фамилия.

В начале XVIII в. Кузьма Обручев попал в Москву, когда Петр I начал строительство русского флота и отовсюду собирали искусных мастеров. Сын Кузьмы, Федор, унтер-офицер Преображенского полка, положил начало военной карьере Обручевых, которые служили в армии.

Третий из известных нам предков Владимира Афанасьевича — Афанасий Федорович (1760—1827) был генералом и инженером. Он возвел несколько крепостей на западе России, за что получил право внести в свой герб изображение крепости. В то время строительство велось частными подрядчиками, что создавало условия для личного обогащения, но Афанасий Федорович Обручев был честен и оставил детям в наследство только «трудолюбивый карандаш», которым писал в последние годы жизни.

Дед Владимира Афанасьевича — Александр Афанасьевич (1796—1866), командир Литовского пионерного (саперного) батальона, был привлечен в 1826 г. к суду по делу Общества военных друзей в связи с волнениями в батальоне. Суд ограничился «строжайшим выговором с подтверждением, дабы впредь был осторожнее» и взыскал с Александра Обручева все издержки казны по этому делу в сумме 963 р. $99^{1}/_{4}$ к.

Во время пребывания на военной службе в 1831 г. в Королевстве Польском Александр Афанасьевич женился на дочери профессора Варшавского университета Франциішека Тымовского — Эмилии. Выйдя в отставку, Александр Афанасьевич Обручев поселился

8

H.J. Mücher

Aspects of Loess and loess-derived Slope Deposits: an Experimental and Micromorphological Approach

ACADEMISCH PROEFSCHRIFT
ter verkrijging van de graad van doctor
in de Wiskunde en Natuurwetenschappen
aan de Universiteit van Amsterdam, op
gezag van de Rector Magnificus,
Dr. D.W. Bresters, hoogleraar in de
Faculteit der Wiskunde en Natuurweten-
schappen, in het openbaar te verdedigen
in de Aula der Universiteit (Oude Lutherse Kerk,
Singel 411, hoek Spui)
op woensdag 10 december 1986,
te 13.30 uur.

PREFACE

Loess deposits cover almost ten percent of the continental area of the world. Due to the excellent properties of loess for agriculture and its applications, mainly in the brick industry, it is an important deposit. However, loess is not fertile in warm arid regions with a precipitation of less than about 250 mm/year (Dr. A.Yair, personal communication, March, 1985). Due to its water retention characteristics which favour high evaporation losses, loess increases aridity (Yair and Shachak, in press).

Loess has received much attention from the earliest farmers and soil scientists, and from scientists of various other disciplines (geologists, geomorphologists etc.) studying the genesis and properties of loess deposits. This has resulted in a very extensive literature on various aspects of loess.

Natural (for example climatic changes and forest fires) and, later on, anthropogenic deforestations and the introduction of agriculture, however, resulted in (accelerated) erosion. This erosion could result in the disappearance of all fertile loess deposits, if no measures are taken. Because of the danger of accelerated erosion, many investigators have focussed attention on the properties of loess about which information is relevant to the development of appropriate conservation methods. To investigate the events which have led to the present distribution of redeposited material and soils, in addition to information on the physical properties of the loess, it is also desirable to be able to distinguish loess which has been transported after eolian deposition from that which is still in situ.

Because of its fine grain-size composition (mainly silt, less clay and still less sand-sized particles) and homogeneous structure the recognition of redeposited loess is macroscopically not always possible in the field.

Information on past events in loess regions can also be obtained from slope deposits and paleosols. These have been interpreted by paleogeomorphologists and Quaternary geologists in the form of environmental landscape reconstructions. In addition to the information which can be obtained about the type of soil formation and intervening periods of transportation, micromorphological interpretations of the slope deposits can also elucidate their mode of formation.

A useful conceptual framework for studying transported soil materials is provided by Butler (1959). In sediment-producing areas soil profiles are truncated during unstable periods, while at the same time they are buried in the sediment receiving areas. During stable periods soil formation keeps pace with the removal of material in the sediment-producing areas, whereas in sediment-receiving areas during the same periods relatively thick surface horizons are formed by the slow deposition of fresh material. Glacial or stadial periods are considered as unstable, and interglacials or interstadials as stable periods. An exception is the formation of anthropogenic slope deposits as a result of disturbance by man of the natural landscape, locally creating an "unstable" period.

It is important to be able to differentiate between slope deposits, and soil and weathering products which in are in situ. Micromorphological analysis can provide evidence of soil formation in situ, which is not visible in the field. In addition to the information which can be obtained about type of soil formation and evidence of transportation, micromorphological investigations of slope deposits can contribute to the reconstruction of environmental conditions during sedimentation. If in Quaternary stratigraphical studies no distinction has been made between loess in situ and redeposited loess, separated by paleosols, this can result in an overestimation of the number of interglacial or interstadial periods.

The aim of this study is threefold, i.e.:

- to establish criteria for the identification of redeposited loess-derived materials;
- to find micromorphological characteristics of the various types of redeposited loess-derived materials, in order to identify their mode of formation;
- to demonstrate how micromorphological analysis can be applied to field studies, involving environmental reconstructions.

In this study, use has mainly been made of experimental and soil micromorphological research, as well as of field studies. The laboratory experiments were carried out in the Laboratory of Experimental Geomorphology of the Catholic University Leuven, at Leuven, Belgium, and in the "Centre de Géomorphologie du C.N.R.S." at Caen, France. The three objectives are re-flected in the threefold subdivision of this study.

In part one, a critical review is given of the loess literature, published mainly during the last decade, giving emphasis to loess occurring in The Netherlands and adjacent countries, and in some well-known loess areas in China and the United States of America. In some cases, where papers are written in a western language, loess occurrences mentioned for other countries are also discussed. It is attempted to provide a "state of the art" report on loess and loess-derived slope deposits (Chapter 1).

A separate chapter describes a case-study on loess and its northern boundary in the southern part of The Netherlands and in the adjacent areas of Belgium and Western Germany (Chapter 2). This section is concluded by a study of loess-derived slope deposits also in the southern Netherlands (Chapter 3).

The second part of this study reports laboratory studies focussed on experimental and micromorphological investigations of erosion and redeposition of loess by water (Chapter 4) and the formation, structure and composition of the resulting deposits (Chapters 5 and 6). After characterisation and interpretation of the mode of formation of the redeposited materials, laboratory experiments are discussed concerning structural modifications in redeposited silt loam due to drying under warm conditions (Chapter 6) and as a result of repeated freezing and thawing cycles (Chapter 7), simulating what happens with redeposited loess in dry-warm and in periglacial climatic conditions.

The third objective, reported in part three, is aimed at demonstrating how micromorphological analysis, in combination with the experimental results, can be applied to field studies, involving environmental reconstructions. Consequently, in part three the applications of micromorphology to various aspects of geomorphological research are described (Chapter 8), followed by a case-study on loess-derived colluvia in southern Limbourg, The Netherlands (Chapter 9).

Part three concludes with a field and laboratory study concerning the (re)deposition of loess, mainly based on an exposed loess profile (475 m long and about 9 m high), located near Nagelbeek, also in southern Limbourg. This profile is Saalian to Pleniglacial Weichselian in age, with on top in valley position Holocene slope deposits (Chapters 10 and 11). In chapter 10 the field evidence for conditions of deposition is considered. In chapter 11 these conditions are compared with the results of laboratory experiments.

CHAPTER 1. LOESS; A CRITICAL REVIEW

1.1 INTRODUCTION

Loess is usually characterised by one or more of the following properties: colour, grain size and mineral composition, type of sediment, mode of formation, structure and way of occurrence. Most definitions of loess have in common that loess is considered to be essentially a silt, of eolian origin (Catt, 1978b; Haase et al., 1983; Mücher, 1973; Pye, 1984; Selby, 1976; Smalley and Vita-Finzi, 1968; Smalley and Smalley, 1983; Worsley, 1983), consisting predominantly of quartz particles (Smalley and Vita-Finzi, 1968; Mücher, 1973), and showing no stratification or bedding (Haase et al., 1983; Mücher, 1973; Smalley, 1975; Pettijohn, 1975; Pye, 1984; Worsley, 1983). However, concerning the carbonate content there is no agreement. According to the definition of the International Union for Quaternary Research (INQUA) Loess Commission (Haase et al., 1983) loess has to be calcareous. In many other definitions of loess the carbonate content is not mentioned, or the loess is described as "mostly calcareous" (Mücher, 1973).

The carbonate content of present loess deposits depends predominantly upon:

- its source area with respect to the absence or presence of calcite ($CaCO_3$) and/or dolomite ($CaMg(CO_3)_2$);
- whether or not decalcification occurred syn- and/or post-sedimentarily, which is largely determined by the climate under which the loess was deposited and/or the climate under which it still occurs.

It is therefore suggested not to use the presence of carbonate as a prerequisite for defining loess. For similar reasons Cegla (1972) came to the same recommendation. Nevertheless, at the same time, he suggested that the carbonate content provides an important indication of sedimentation and conditions of diagenesis.

In the light of the above, the following definition of loess is proposed:

> "Loess is an eolian, clastic, non-volcanic, mostly unconsolidated, commonly carbonate-containing, porous, yellowish brown (10 YR 5/6), pale yellow or buff coloured (locally grey, brown or red), deposit, which consists mainly of silt-sized quartz particles, with usually less than 20 % clay (< 2 µm) and less than 15 % sand (50-2000 µm), without any stratification or bedding, showing an ability to maintain vertically cut faces, and which mantles the landscape".

Very many publications have appeared on loess in many journals and books, in various languages. In this respect the work of I.J.Smalley is of invaluable importance. In 1975 Smalley published the Benchmark Papers in Geology, volume 26 (Loess, lithology and genesis) in which key papers written between 1834 to 1973 are assembled. Smalley (1980) compiled a partial bibliography on loess which details over 1000 contributions to the loess literature. Smalley and Davin (1980) published a historical bibliography of New Zealand loess.

The "Loess Letter", an informal newsletter, is published twice a year by the Quaternary Research and Geological Engineering Groups of the University of Waterloo, Ontario, Canada, on behalf of the INQUA Loess Commission. In the "Loess Letter Supplements" bibliographies are published on certain subjects, for example "Loess & Agriculture" (Kwong and Smalley, 1983) and "The Hydrology of Loess, 1883-1982" (Sweeney and Smalley, 1984).

The purpose of this chapter is to review the literature on loess published during the last decade, giving emphasis to papers from The Netherlands and adjacent countries. It forms an extension of chapter two, concerning a case-study on loess and its northern boundary in the southern part of The Netherlands, and in the adjacent areas of Belgium and Western Germany.

The loess has many uses; these include raw material in the brick industries, moulding sand, slurry in offshore borings, and thinner in extermination materials used in agriculture. Above all, however, loess as a deposit, as well as a constituent, is of extreme importance as high quality farmland covering almost 10 % of the continental area of the world. Very recently Smalley (1984) stressed the fact that the loess areas of the world coincide with the areas of high agricultural productivity and that even small quantities of loess in the soil are economically important.

Loess has, however, also less favourable characteristics, such as:

- it remains longer wet during the spring;
- it is sensitive to slaking;
- it has a high erodibility ;
- it is not fertile in warm arid regions with a precipitation of less than

about 250 mm/year (Dr. A.Yair, personal communication, March 1985; Yair and Shachak, in press).

In view of the importance of loess as an agricultural resource, it is essential to ensure conservation, and to guard against loss of loess and loess-containing deposits by erosion.

In the ensuing paragraphs, the distribution and characteristics of the loess, the source area, transportation, deposition, dating and modifications in the loess after sedimentation (inclusive erosion) are considered in turn.

1.2 THE DISTRIBUTION OF LOESS

The most important and thickest loess deposits occur in the northern hemisphere in a belt stretching from Normandy through northern France (Coutard et al., 1969; Jamagne et al., 1981; Lautridou, 1979) into Belgium (Mees and Meijs, 1984; van Vliet and Langohr, 1981) and the southern part of The Netherlands (Kuyl, 1975, 1980; Koelbloed, 1975; Mücher, 1973), West Germany (Brunnacker, 1978), East Germany, Poland (Piest and Ziemnicki, 1979) and through the basins of southeastern Europe, Austria, Czechoslovakia, Hungary (Pesci, 1982), Rumania and Bulgaria (Haase et al., 1983; Smalley, 1975, p. 246; Stoilov, 1984) into the Russian plains of Soviet Central Asia, the Ukraine and Siberia (Gerasimov, 1973; Haase et al., 1983; Pye, 1984). The loess belt extends eastwards into northwestern China in the middle reaches of the Hoanghe River, including the entire loess plateau and a small part of the Mongolian plateau (Derbyshire, 1983a, 1983b; Pye, 1984; Wang and Zhang, 1980; Zhu Xianmo et al., 1983). The major loess deposits of the world are generally less than 25 m thick.

Local occurrences of loess are found in Switzerland (Frei, 1974), Alsace (Lautridou, 1979) and in the United Kingdom. In England calcareous loess forms a continuous deposit mainly in areas adjacent to the Thames estuary in northern Kent and sout-east Essex. Thin loess, often mixed by cryoturbation, with subjacent deposits, is widespread in parts of south and east England, southern Wales and north-east Essex (Catt et al., 1974; Catt, 1978a; Eden, 1980; Worsley, 1983).

Relatively thin loess deposits are found in northern Afghanistan, Iran (Bal and Buursink, 1976), Pakistan (Pye, 1984) and in the Kashmir Valley of India (Agrawal et al., 1979). In the Mediterranean area mostly sandy or loess-derived deposits occur, for example in Israel (Yaalon and Dan, 1974), Greece, south-east Spain, Turkey and Tunisia (Brunnacker, 1973, 1979, 1980; Brunnacker et al., 1969; Brunnacker and Lozek, 1969).

In Africa, apart from in Tunisia, loess deposits have only been reported from the south of Kano in northern Nigeria (Bennett, 1980; Smith and Whalley, 1981; McTainsh, 1984).

In America thick and extensive loess mantles are found in the Great Plains of North America and along the Mississippi Valley (Pye, 1984; Piest and Ziemnicki, 1979), and in Argentina (Smalley, 1975, pp. 195-205). Smaller loess deposits are found in Washington, Oregon, New Mexico, Texas (Pye, 1984) and in the Teays River Valley in Ohio (Thompson et al., 1981).

Locally derived loess deposits have been reported from western Canada and the Cypress Hills of southern Alberta (Catto, 1983; Smalley, 1984), Alaska, Greenland and Antarctica (Smalley, 1975, p. 194), Victoria in Australia (Pye, 1984) and New Zealand (Milne and Smalley, 1979; Selby, 1976).

On the European continent, loess deposits are found from near sea level up to 200 m + N.A.P. as has been reported from The Netherlands by Mücher (1973). The highest deposits occur in China at altitudes between 2000 and 2400 m above sea level (Derbyshire, 1983b; Wang and Zhang, 1980). In plateau position the thickness of the loess in The Netherlands ranges from 10 to 20 m; in hilly areas it varies mostly between 2 and 5 m in thickness (Kuyl, 1980; van der Marel and van den Broek, 1962). The Hungarian loess is 5 to 25 m thick (Pesci, 1982) and in Bulgaria the loess thickness may exceed 100 m (Haase et al., 1983). In China the thickness of the loess cover ranges from less than 50 m to more than 200 m, but is mainly between 30 to 80 m (Zhu Xianmo et al., 1983; Wang and Zhang, 1980). In the region of the Hoanghe River the world's thickest loess deposits occur (335 m), just north of Lanzhou City (Derbyshire, 1983b).

In regions with extensive loess blankets, the loess mainly occurs as a distinctive deposit at the surface. Thin loess deposits can be found near the boundary of these extensive loess sheets, or in areas where only small, mostly locally derived deposits exist. These thin deposits are often incorporated into the subsoil by cryoturbation, biological activity and lateral transport after primary eolian deposition, and are mostly sandy. Examples of these incorporated loess occurrences in the subsoil can be found near the northern boundary of the loess belt in The Netherlands and in adjacent areas of Belgium and West Germany (Koelbloed, 1975; Kuyl, 1975; Meys en de Lang, 1983; Mücher, 1973), in the Black Forest in southern Germany (Maus und Stahr, 1977), in parts of south- and east-England and south-Wales (Catt, 1978a) and in western and southern Canada (Catto, 1983; Jungerius and Mücher, 1972; Smalley, 1984).

In addition to occurrences at the surface or as an incorporation in the subsoil, loess may also be found as a buried deposit. Buried loess deposits are mainly sandy and have up until now only been reported from a very limited number of locations. For example in The Netherlands: buried loess occurs in the subsoil of the province of Brabant, where it is buried by coversands (Kuyl, 1975; Koelbloed, 1975; Meijs en de Lang, 1983; Vandenberghe and Krook, 1981). It occurs also in the subsoil northeast of Zwolle, at the same latitude as the surficial loess deposits south of Bremen, northern Germany (Koelbloed, 1975). In Poland loess occurs also beneath glacial and fluvioglacial deposits (Mojski, 1968).

Recent maps of the surficial and occasionally buried distribution both of characteristic and sandy loess occurrences, often with thickness indications, have been published, from northwest France (Jamagne et al., 1981), The Netherlands and adjoining areas in Belgium and Germany (Kuyl, 1975, 1980; Koelbloed, 1975; Meijs and de Lang, 1983; Mücher, 1973), United Kingdom (Catt et al., 1974; Catt, 1978a), Hungary (Pesci, 1982), Russia (Gerasimov, 1973), China (Derbyshire, 1983a, 1983b; Pye, 1984; Wang and Zhang, 1980), New Zealand (Selby, 1976) and North America (Piest and Ziemnicki, 1979; Pye, 1984). Pye (1984) has published a map of the global distribution of loess. The new loess map of Europe, prepared by the Commission on Loess (INQUA) will be published in Petermann's Geographische Mitteilungen, probably in 1986 (Haase et al., 1983).

1.3 LOESS COMPOSITION

1.3.1 Grain-size

The grain-size distribution of a typical loess deposit shows a dominant silt fraction (2-63 µm), with usually less than 20 % clay (< 2 µm) and less than 10 % sand (> 63 µm).

In The Netherlands and Belgium the silt content is mostly 70 % or more (Felder et al., 1980; Kuyl, 1975, 1980; Mücher, 1973; Van den Broek, 1958/1959).

In France the loess consists of 60-80 % silt in the fraction 20-50 µm, and contains less than 15 % sand (Jamagne et al., 1981; Lautridou, 1979).

Kowalinski et al. (1972) compared the Polish loess with the Dutch and Chinese loess and concluded that the loess in Poland is more sandy, containing 20 % sand compared to 9-10 % in The Netherlands and China.

The median size value of the Middle European loess varies normally between 30 and 35 µm (Brunnacker, 1973, 1980). Near Caen in France this value varies between 26 and 36 µm for the calcareous and between 23 and 32 µm for the non-calcareous loess (Coutard et al., 1969).

In the Mediterranean area loess composition varies greatly. For example, in N. Greece (Kitros) and in S.E.Spain (Granada) the loess contains respectively 67 % and 61 % silt, whereas in Tunisia (Oratmata) and Israel (Kisufim) the deposits contain only 30 % silt and 40-50 % sand (Brunnacker, 1980). The sediments from the last two locations can therefore hardly be regarded as loess. Possibly one could qualify them as loessoid, the term proposed by Pye (1984) for sediments occurring in many desert fringe areas influenced by aeolian dust deposition. One must be aware, however, that the term "loessoides" was already used in 1925 by F.H.van Rummelen (see Van Rummelen and Van Rummelen, 1950) to indicate loess-like deposits which mainly consist of weathering products of Senonian limestone, and during redeposition, mainly by solifluction and overland flow, were mixed with Tertiary and Quaternary materials. Only a minor part of the loessoides is derived from winnowed materials from the surrounding area, which were incorporated in the loessoides during their formation. The term loessoid therefore might cause confusion.

According to Brunnacker (1979) the strong variation in grain-size and carbonate content of the Mediterranean loess is due to differences in source areas.

The loess in China contains mostly more than 60 % silt (Wang and Zhang, 1980; Zhu Xianmo et al., 1983).

Although the loess in Canada (Cypress Hills) shows a pronounced mode in the silt range, the sand content varies between 4.5 and 23.4 %, and the clay content between 1 and 10.4 % (Catto, 1983).

In general, however, the silt content of loess ranges between 50 and 80

%, with a median size value of 20-40 μm, which is in agreement with Pye (1984).

The grain-size distribution of typical loess is mostly positively skewed, and the skewness lies in the range of +0.3 to +0.7 (Pye, 1984). The skewness of the Chinese loess is between +0.4 and +0.9 (Derbyshire, 1983b).

In the silt fraction the coarser particles between 16 and 63 μm are usually dominant, exceeding 55 %. In England these make up more than 45 % of the Kent loess (Catt et al., 1974). The fine silt classes, 8-16, 4-8 and 2-4 μm are generally 5-10 %, 3-5 % and less than 3 % respectively. The sand fraction contains only two classes, 63-150 and 150-210 μm, which are in general less than 8 and less than 2 % respectively. Grains larger than 250 μm in diameter hardly occur in pure loess.

For detailed variations in size classes of loess deposits in Western Germany reference is made to Peinemann and Garleff (1981) and Siebertz (1982).

Although the coarse silt fraction (16-63 μm or 20-60 μm) characterizes the grain size composition of the loess, it is not advisable to call this range loess-size, as has been proposed by Smalley and Smalley (1983). This fraction can also be formed in totally different environments, without any connection with eolian formation. Among others in marine, fluviatile and lake deposits. This term causes only confusion and promotes misinterpretation, and must therefore be avoided.

It has to be kept in mind, however, that considerable differences in grain-size composition can be the result of differences in laboratory methods and choice of size class boundaries. Real differences may be caused by soil formation (including weathering and diagenesis), pedoturbation (including bioturbation) and frost action. The last two processes can cause coarser and/or finer material to be incorporated from the substratum. In addition the composition can be influenced by the introduction of material other than loess by wind, water or human activity.

Sedimentary characteristics of primary loess can also be markedly modified by redeposition during overland flow, with or without simultaneous rainfall, as has been demonstrated by the experiments of Mücher and De Ploey (1977) and Mücher et al. (1981). For this reason it is necessary to

use the unmodified C horizon material when comparing different loess deposits from various areas. But even then it is possible that the primary sedimentary characteristics are modified as a result of redeposition by afterflow (i.e. overland flow without splash), not visible with the unaid eye, but microscopically observable in thin sections of undisturbed samples (Mücher and Vreeken, 1981).

Examination with the scanning electron microscope (SEM) has shown that the majority of silt-sized loess particles are blocky and angular or subangular, but that also rounded particles occur with the size of coarse silt or fine sand (Cegla et al., 1971; Catto, 1983; Wang and Zhang, 1980; Derbyshire, 1983b; Pye, 1984). Besides glacial grinding several other processes, such as frost action, eolian abrasion and salt weathering, are also capable of producing angular or subangular silt grains with sharp edges. Consequently the nature of the source area and the mode of formation can not be identified only on the basis of particle shape and texture (Pye, 1984).

The weight percentages of the individual size fractions can be used to calculate the degree of fineness (D.F.). This index facilitates comparison of various samples. From the percentages by weight the summation values are calculated (total of i fractions is 100 %), starting from the clay fraction, expressed as:

$a_i = \sum_{j=1}^{i} f\,j$ (for example: a_3 = f 1 (< 2 μm) + f 2 (2-6 μm) + f 3 (6-20 μm))

Thereafter the summation values (a_1 to a_i) are added once again, also from fine to coarse. The end sum is divided by the number of grain-size fractions (n), giving the degree of fineness (D.F.), expressed as:

$$D.F. = \frac{1}{n} \sum_{i=1}^{n} a_i$$

After estimating the mean degree of fineness of the various vertical profiles, lines of the same degree of mean fineness, subdivided into classes, can be constructed. These lines are so-called isokatharoses (Gr.: katharos = purity). This degree of fineness was introduced by Schönhals (1955). Siebertz (1982) applied this method and constructed isokatharoses from the Eemian eolian sediments (loess and sand) on the surface in the Lower Rhine region, NW of Düsseldorf (W. Germany). His D.F. values vary for loess sediments from 72 (with 2-3 % sand, 630-200 μm) to 67/68 (with 10-11% sand).

1.8.4.2 Mass movements

Although many types of mass movement are described in the literature, in comparison little is known concerning the effects of mass wasting processes in loess. The following statement of Selby (1982, p. 117) is therefore particularly applicable for mass movements in loess: "Recognising the nature of a process from the debris it leaves behind is not always easy and the group of processes - debris slide, debris avalanche, debris flow, collectively called translational slides - are not always distinguishable from each other".

The homogeneous structure, the fine texture (mainly silt) and the fact that often more than one mechanism has contributed to the ultimate formation of the deposit, hamper the studies of mass movements in loess.

Movements related to creep are mostly not visible in the field. Direct measurements of soil creep in the loess revealed movements of several mm/yr. According to Selby (1982), in humid climates creep produces downslope movements of 1-3 mm/yr on slopes of 15° to 30°. In vegetation-covered soils the creep rates can be even lower, e.g. 0.1 mm/yr, whereas in cold climates, where freeze-thaw processes are involved in the formation of soil creep higher rates have been measured (up to 0.5 m/yr).

Laboratory experiments (Coutard and Mücher, 1985) during one year on laminated loess material with a slope angle of 7-8% revealed a mean frost creep downslope movement at the surface of 1 cm per cycle (in total 18 freeze-thaw cycles), decreasing rapidly with depth, and was almost zero at a depth of 10 cm. According to micromorphological investigations by Van Vliet-Lanoë (1982, 1985) and Van Vliet-Lanoë et al. (1984), frost creep deposits are characterised by platy aggregates, formed by ice lenses, slipping sheet by sheet in a downslope direction without prominent deformation. This fabric was observed in the field and could be reproduced in the laboratory as well. The occurrence of fragments of sedimentary argillaceous laminae, displaced laterally and vertically, creating broken and discontinuous clay layers, sometimes rearranged into step-like features in the thin sections of the experiments of Coutard and Mücher (1985), could be related to the above-mentioned frost-creep mechanism.

The recognition of loess-derived solifluction deposits and the process responsible for their formation, is still a problem. The first definition

of solifluction is given by Anderson (1906): "this process, the slow flowing from higher to lower ground of masses of waste saturated with water (this may come from snowmelting or rain), I propose to name solifluction (derived from solum = soil and fluere = to flow)". Later terms are introduced as "congelifluction" (Dylik, 1951) and gelifluction (Washburn, 1967), to stress the influence of frozen soil on the formation of these deposits and to separate them from those due to frost creep. In the field deposits with divergent structures, among others, with streaks or series of strata, tongues (Cegla, 1972) or with the occurrence of various components from fine to coarse in a chaotic way, are described as solifluction deposits, and are consequently supposed to be formed by this process.

Stability experiments of loess blocks after 50 freeze-thaw cycles by De Ploey (1973) gave rise to mean downslope movements after thaw of 0.52 mm. A flow movement did not occur, although the final water content largely exceeded the plastic limit (water content: 18.6 %) and the liquid limit (water content 21.9 %) of Atterberg. This was especially the case at the base of the loess blocks, where values up to 33 % water were recorded. The experiments demonstrated the relatively high resistance of loess, at water contents above the liquid limit, to plastic flow. He concluded that it is very unlikely that on loess slopes of a few degrees, thin solifluction layers (in the order of centimetres or decimetres) would have been deposited during the Weichselian. In addition, the results are in favour of the idea of a dominant extended frost-creep movement, which could have effected loess deposits rather than a plastic flow parallel to the slope. When additionally water was supplied to the surface of the loess block, followed by runoff, microslumping (a type of slide mass movement) occurred.

Van Vliet-Lanoë (1982, 1985) and Van Vliet-Lanoë et al. (1984) describe gelifluction in thin sections as deposits characterised by well-rounded aggregates with a silty cap on several faces, deformed by rotation of the material, rolling over each other, when the sediment is temporarily supersaturated. Van Vliet-Lanoë observed this type of deposits in thin sections of samples from, for example, northwestern Spitsbergen. Up until now, however, it has not been possible to reproduce this fabric under laboratory conditions.

Nevertheless, besides slumping other mass wasting features, such as earth, mud or loess flows can be formed under wet conditions on unvegetated, fresh, slopes of roads, cut into the loess mantle. This implies that under certain conditions loess indeed does flow. The necessary supersaturation of the loess may be due to a combined effect of thawing, raindrop impact during rainstorms, and overland flow. In this case, however, the question remains whether this translocation is still a mass movement or is it already to be regarded as material transport in water with a very high sediment concentration? The thickness of these deposits is mostly several centimetres, with a displacement of several metres. Such mud flows show no characteristic structure and fabric in thin section, they are rather massive, hard when dry and frequently contain numerous vesicles (Van Vliet-Lanoë, 1985).

Buried mass movement features can also be observed in Weichselian loess deposits. For example, Vreeken and Mücher (1981) locally found in the Nagelbeek pit (southern Limburg, The Netherlands) on a slope of a buried, filled-in paleochannel immediately above the truncated Rocourt paleosol, mass-moved lobate inclusions (several centimetres thick and with a length of 10-20 cm). They consisted of Rocourt paleosol material, containing macroscopic flow structures. In thin sections the lobes were similar to in situ Rocourt paleosol material with unsorted silt loam, without vesicles, and additionally angular pedogenic aggregates. The structures may have resulted from mass movements of the flow or slide type. The angular aggregates could point to a sliding movement, or might have resulted from mass movements while the aggregates were in a rigid state. The material in between the lobes only occasionally contained laminae with well-sorted silt grains (without clay), suggesting deposition by afterflow or meltwater flow. Several other mass deformation features in the Nagelbeek pit are described by Vreeken (1984).

Dry loess flow mainly occurs on slopes of unconsolidated, non-cemented loess in (semi)arid regions, as for example in China (see also Selby, 1982).

In conclusion it can be said that there is an urgent need for a classification system of various loess-derived mass wasting features, according to their mode of formation and their resulting characteristic structures. Only after such a classification has been established, can the mass movement deposits serve as reliable indicators of environmental conditions in the past.

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SAHARAN DUST AND DESERT LOESS: EFFECT ON SURROUNDING SOILS

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Sahara is the major region for producing and exporting dust to the surrounding areas (Morales, 1979; Goudie, 1983). Dust transported westward amounts to some 260 million tons per year, mostly falling into the Atlantic ocean but also reaches the US coast. Dust transported eastward amounts to some 70 million tons per year, mostly deposited in the Mediterranean sea with significant amounts reaching Egypt and Israel. Due to less frequent events smaller amounts are transported northward across the Mediterranean to Europe, where dust contributes significantly to many of the shallow limestone- and basalt-derived soils in Greece, Italy and Spain. Southern and southwestern transport results in deposition in Nigeria, Canary Islands and as far as South America.

Only areally small but specific desert environments are dust producing. These include flood deposited debris, coarse to fine grained, on alluvial fans (glacis) and in broad wadis. Physical and chemical weathering in the steeply sloped rocky desert mountains prepares the material for periodic removal by runoff after rain storms. Terminal depressions with fine grained calcareous basin sediments, where salt crystallization continues to disintegrate the particles, are an additional important source of dust (Fig. 1). The widespread stable geomorphic surfaces on interfluves (regs) and sand seas (ergs) are not significant sources and supplies of dust.

Three modes and distances of transport, from short distance within the drainage basic to global long distance (over 1,000km) can be distinguished. Long distance transport of large dust clouds, up to 5 km high, distributes mainly the finer grained dust (<30 μm) over distance exceeding 1,000 km. Five to ten dust storms per year is a common occurrence. With a deposition rate of less than 2 um per event (2.5 g/m^2) this kind of accretion is generally incorporated into the local soil (or ocean sediment) and assimilated by the ongoing soil forming process. Medium distance transport is mainly downwind from the major wadis and river valleys for a distance of 50 to 200 km and includes particles in suspension up to 100 μm in diameter. In such cases both thickness of deposition and grain size decrease (exponentially) from the source. Where deposition rate exceeds 40 μm per year (50 g/m^2), over a long period of time, distinct loess deposits are formed several metres thick (over 200m in China). Short distance local dust transport within low-order drainage basins is more important in periglacial melt environments than in deserts (Smalley, 1975; Pye, 1984).

These eolian deposits become the parent material for locally controlled soil forming processes (Yaalon and Ganor, 1973). Due to their position on the fringes of the desert they are sensitive to past and present climatic fluctuations in the dust deposition rate, intensity of erosion and soil forming processes, and they frequently preserve several paleosols as the section grows upward, in response to changing environmental conditions. At present only three regions with Sahara-derived desert loess have been studied, but more are likely to be recognized in the future.

The best studied area is in the arid to semiarid Negev, Israel, where the up to 12 m thick Netivot loess section contains six cycles with pedogenic calcic horizons of Upper Pleistocene and Holocene age. The light yellowish-brown (10YR) to brown (7.5YR) clayey silt soils range from Calciorthids to Haplargids (Xerosol or Yermosol) and the clay minerals are dominated by montmorillonite with some pedogenic palygorskite (Dan et al., 1981). The distinct paleosols indicate climatic cycles of about 20,000 years duration within the semiarid-arid climatic range (up to 350 mm precipitation).

The Zaria loess mantle of the Kano plain (northern Nigeria) shows a clear decrease of grain size from the source area in the Chad Basin, with a sand dune mantle in between. The loess mantle is underlain by crystalline rocks of the Basement Complex and in this subhumid climate (precipitation up to 1,000 mm) results in brown (10YR) leached Haplustalfs (Luvisol) soils with argillic horizons, red mottles and occasionally poor to impeded drainage (Bennett, 1980; McTainsh, 1984). Illite and kaolinite are the dominant clay minerals. Total thickness or the presence of paleosols has not been reported.

In the Matmata plateau of southern Tunis there is a loessial cover less than 15m thick with up to five paleosols. Its origin is in the basin of the Djerid chott (sebha) and its soils are Calciorthids or Gypsiorthids (Yermosol-Solonchak) with calcic and gypsic horizons reflecting the low precipitation (about 200 mm). The soils are rich in smectite and palygorskite (Coude-Gaussen et al, 1984; Paquet et al, 1984; Ballais and Balland, 1983).

The loess-derived soils thus differ considerably in their morphology, clay mineralogy and carbonate content, reflecting in each case the source area and the superimposed influence of the soil forming process. They are generally unstable and sensitive to climatic change. Their paleosols are good indicators of paleoclimatic fluctuations where problems of dating can be overcome. Clay minerals and additional indices can be used to trace the source area in comprehensive studies of the Saharan dust paleogeography and its loess derived soils. They are no doubt more common than present data indicate.

Beyond the desert fringe regions, with more or less thick loess mantles, frequently severely eroded because of their poor stability to water erosion, there are soils in which desert dust accretion has significantly altered the ongoing pedogenic process and those where the slow dust accretion (less than 10 μm per year) have not significantly altered the soil forming process even though it may form up to half of the soil volume (Yaalon and Ganor, 1973). To the first category belong the red (5YR) Hamra sandy clay loams (Rhodoxeralf, Luvisol) of the Coastal Plain in Israel, where all the clay is of eolian origin as the weathering of the quartz sand could not produce it. To the latter category belong the basalt-derived Vertisols and Alfisols, (e.g. Canary Islands and Israel) where the silt size quartz content can only be explained as of airborne origin, and the limestone derived Terra Rossa soils of the Mediterranean countries (Greece, Italy, Spain, Israel) where the silt size quartz was not present in the limestone and oxygen isotope ratios confirm its foreign origin (Macleod, 1980; Jackson et al., 1982; Rapp, 1984).

Dust material deposited and redeposited within the desert is partially trapped in surficial gravels of various types (hamada, serir, reg, talus, lithosols), on biogenic crusts (algae, mosses, lichens), or on salt crusts, frequently with decreasing rate over time as the surface becomes plugged or otherwise sealed and impervious (Gerson et al, 1985). Exceptionally up to one meter of gravel-free dust can accumulate below a gravelly desert pavement. **Wet sebha surfaces also trap some dust.**

The Nile delta soils of Egypt no doubt have also been enriched by deposition of fines from the dust clouds passing over it from the Sahara, and much of their phosphate may be Sahara derived rock apatites which are more common in the north African source beds than in the Ethiopian plateau. In each case the proof of the eolian contribution from the Sahara must use specific and different methods, suitable for each particular case. As more data become available and accumulated, the source area specifity, the variability in rates of supply and deposition along specific trajectories will become better understood for both present and past conditions. It is a necessary prerequisite to predict the effect of man's manipulation of nature and of climatic changes on these processes for the near and distance future.

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DESERT DUST SOURCE AND DEPOSITION SYSTEMS