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LLO website: www.loessletter.com check here for conference reports and random recent loess references.

Collapsing Soils Commentary (for IAEG/C18) website (http://construction.ntu.ac.uk/graduate_school/Research/Geohazards/Synopsis/default.htm) C18 Secretary: Ian Jefferson at above address

Dirtmap project: An international project to study aeolian dust; see LL42 for some details; based in Jena, Germany. Contact Karen Kohfeld (kek@bgc-jena.mpg.de) Website (www.bgc-jena.mpg.de/bgc_prentice/start1.html)

Loess Letter LL 46 October 2001

LL46. Loess Letter is the newsletter of the Loess Commission of the International Union for Quaternary Research INQUA, and the Collapsing Soils Commission C18 of the International Association for Engineering Geology & the Environment IAEG. It is published by the GeoHazards Group in the School of Property & Construction at Nottingham Trent University. It appears twice a year, usually in April and October; edited by Ian Jefferson & Ian Smalley. It supports the Dirtmap project (organised from the Max Planck Institute in Jena).

LL46 is a special issue on the occasion of the International Conference on Sustainable Economic Development and Sound Resource Management in Central Asia (3-5 October 2001, Tashkent, Uzbekistan). We see loess as an important resource in Central Asia and support programmes to investigate its nature, distribution and properties. Loess soils are a major agricultural resource and deserve to be developed and managed carefully and sensibly. Loess ground has the capacity to support a sustainable lifestyle – if it is used properly and responsibly.

1. eluvial-deluvial loess-like rocks ~2-5m thick
2. deluvial-proluvial loess ~5-30m
3. proluvial loess ~10-100m
4. alluvial-proluvial loess ~0.5-30m
5. alluvial-delta loess-like deposits ~20m
6. alluvial gravel, sands, boulder gravels etc ~5m
7. deluvial-proluvial crushed rocks etc ~1m
8. saline regions and bogs
9. aeolian sands
10. eluvial-deluvial formations ~1m
11. pre-Quaternary parent rocks
LOESS IN UZBEKISTAN

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Abstract

Loess is widespread in Uzbekistan; in fact Uzbekistan and neighbouring regions in Central Asia rank as one of the world's major loess regions. This loess, the basis for productive soils in most of the country, is a key part of the Uzbek economy, and the degradation and loss of capacity in the loess soils is a major economic drain. The economic health of Uzbekistan requires that the loess soils be understood and nurtured, be appreciated and used carefully. There is a recent history of catastrophic misuse, and much restoration action is required.

Keywords: Loess, hydrocollapse, ground improvement, development, sustainability

1. Introduction

In Soviet times the loess in Uzbekistan was studied, largely by workers from the Uzbek Academy of Sciences, and essentially led by G.A. Mavlyanov. His major monograph (Mavlyanov [1]) is still the basis for loess investigations in this region, and contains key loess maps. Under the Soviet academic/scientific system each region tended to develop one single accepted authority; for example V.P. Aver'yanov in Rostov-on-Don, or M.P. Lysoenko in Leningrad, E.M. Sergeev in Moscow, V.T. Krutov in Kiev. Lately these loess authorities had large influence, in a very authoritarian system, and influenced the direction of Soviet loess research. Geographical research was particularly influenced by I.P. Gerasimov the Director of the Geographical Institute of the whole Soviet Academy of Sciences, having a special interest in loess, had large scale influence. Unfortunately he subscribed to the Dokuchaev-Dimo-Berg view of loess formation and this led to a situation where the true nature of loess deposits and loess soils was not appreciated (see Smalley & Rogers [2]). There are problems in untangling the Soviet legacy, and the INQUA Loess Commission is actively involved in this process.

The major city in the Central Asian region is Tashkent, and this is founded on loess, near to the slopes of the Tien Shan range. Tashkent is a leading 'loess city' – like Kyiv its location and construction factors relate very strongly to the loess. A basic reference paper for loess in the Tashkent region is Smallley [3] but the basic model for the formation of the Tashkent loess is usually called the 1978 model, after the first outline proposals in Smallley & Krimsky [4]. The 1978 model suggests that the Uzbek loess is a true mountain loess with the particles being produced in the mountains of High Asia and largely transported by the Amu-Darya and Syr-Darya and related rivers. Particle production is a powerful test of loess forming theories and certainly demonstrates that the Berg 'eluvial' theory cannot be true. To make a loess deposit, loess material must be available. For loess material to be formed large geo-energy is required. Major loess deposits are associated with
regions where large amounts of geo-energy were available in the Quaternary and late Tertiary times; e.g. the glaciated regions of north Europe and North America, or very high tectonically active mountain regions. Where there was no glaciation and no high active mountains there tends to be no significant loess, e.g. Australia, Africa.

2. Process

Yeleasev [5] identified five theories that had been advanced to explain the origin of loess soils in Central Asia; these were the pluvial theory of G.A. Mavljanov, the alluvial theory of Yu.A. Sitkovsky, the deluvial theory of N.P. Vasil’kovsky, the soil theory of I.P. Gerashin and the aeolian theory of V.A. Obruchev. A careful examination of all the processes involved in the formation of the Uzbek loess suggests that all of these investigators may have certain factors and validities to contribute to the whole complex picture. The basic aeolian ideas of Obruchev are certainly true, loess material is blown into position to form loess deposits, and the position of Tashkent in the Tien Shan foothills suggests that there has to be a pluvial contribution to the local soils.

The 1973 ‘Tashkent’ model of loess formation in Central Asia used the PTO System to describe a series of events which led to the formation of loess deposits. The PTO System [5] breaks down the whole process into a succession of Provenance events. Transport events and Deposition events; it was supposed to divide the whole process into scientifically accessible parts, which when assembled, would indicate the true history of loess deposits.

Figure 1: Distribution of all deposits around High Asia (after Assalley et al. [7]): 1 Central Asian loess, 2 Tarim basin loess, 3 North China loess, 4 North China alluvial plain, 5 Bengal delta, 6 North India alluvium, 7 Indus alluvium, 8 Irrawaddy delta, 9 Mekong delta.

Figure 1 shows the setting of the Central Asian loess, with respect to the disposition of all deposits around High Asia. High Asia is the extremely uplifted region caused by the crustal overlap resulting from the collision of tectonic plates. This is a region of great height, of great tectonic activity, of much release of geo-energy, of extreme climatic variability, and it is a great source of all materials, which goes to supply some of the world’s major loess deposits. The region shown in Figure 1 is vast; zone 1 is the Central Asian region containing the loess of Uzbekistan; zone 3 is the Chinese loess where the various F, T and D factors have combined effectively and produced deposits with vast area cover and great thickness (see Smalley & Krinsley [4]). In the zones around High Asia it is observed that the southern deposits in more humid climates often stay as alluvium and do not reach the T stages for conversion to loess; but in the more arid north loess deposits tend to form.

Figure 2: Loess in Central Asia (after Kriger et al. [8]). Shaded areas are loess regions; numbers are sampling sites and study areas. Note 2 Dushanbe, 7 Tashkent, 13 Frunze, 18 Alma-Ata.

The actual loess deposits in and around Uzbekistan are shown in Figure 2. This is by Kriger et al. [8] and shows loess cover and sampling sites in the region which Kriger calls Central Asia and southern Kazakhstan. The loess might be divided into two regions; the truly desert part obviously connected to the two rivers, and a part closer to the mountains, a peri-montane region, containing the Tashkent loess. When Smalley [3] was describing his model of the Tashkent loess he concentrated more on the origins of the desert related material; his model can be revised to take more account of the mountain regions, and perhaps reconcile it with Mavljanov’s ‘pluvial’ loess. Mavljanov [1] certainly mapped pluvial loess in the Tashkent region.
A mixed deposit is formed in the foothills region; some sorting may have occurred but mixed deposits should predominate. This stage was described by Smailey [3]; it represents a poorly defined event but it is difficult to introduce more precision. D1 is the result of T1; necessary early stages in the loess deposit forming process.

Some complex transportation activity here; some particles may be raised by the wind from the mixed deposit and carried away in suspension but the major activity is probably (in terms of eventual loess deposit formation) still fluvial and involves the introduction of the finer particles (sand size and smaller) into the major rivers-an event which leads directly to

Transport out into the desert regions by (in particular) the Amu-Darya and Syr-Darya. These rivers are/were powerful transporters of suspended material, in fact Suslov (p.472) [10] claimed that “There is no other river in the world that carries as much suspension material as does the Amu-Darya”. This major river is a key factor in loess deposit formation, as are many larger rivers. The Danube, the Mississippi, the Missouri, the Yellow are all great loess providing rivers. There is a classic simple picture of loess material distribution. Loess material is formed and introduced into large river systems, it is carried considerable distances and deposited as floodplain deposits, aeolian transport then moves the silt material a relatively short distance to form a classic airfall deposit, with all the defining loessic qualities. The Amu-Darya and Syr-Darya fill this simple model, T3 is the major movement event.

Relatively well sorted floodplain deposits are formed, in particular of particles in the size range 10–50 um; Suslov recorded 64.3% of these particles in the Amu-Darya alluvium. These are the raw material for desert loess, and it is the rivers which place them in the desert setting, as D2 alluvium.

Although the sorted deposits have a relatively high stability their desert situation exposes them to erosion by sand grain impact and this injects silt-sized particles into the airstream [11], [12] and they are transported in suspension. Many only travel short distances but some are carried out into the Kyzyl Kum desert.

Deposition close to rivers, but also at desert fringes. The formation of well-sorted loess deposits with silt sized particles and open structures; nutrient rich but prone to hydroconsolidation; most material delivered by the T4 stage but some direct from D1/T2.

Post-depositional changes. The D3 deposit may be more stable than the D2 deposit because it is less exposed to desert processes. Some time and clay minerals may accumulate, these will stabilise the loess structure and produce the classic loess composition.

The 1978 model ended at D4 but T5 has been added to emphasize the fact that loess soils are unstable in the landscape; they are prone to soil erosion, so event T5 is further aeolian movement as a result of soil erosion. In looking at the formation process of a loess deposit in historical terms it now becomes important to pay close attention to stage T5.

So the event sequence now has ten stages. The important event that this approach added to the studies of Central Asian loess was the T1 stage; the relative importance of the subsequent T and D stages can be discussed and modified, but a clearly identified P1 gives the operation a firm basis.

### Commentary

An important study of loess in Uzbekistan, and in the rest of Central Asia is that by Rozyczki [13], he had access to the work of Mavlyanov and his Tashkent Institute; he wrote “The loess deposits of Middle Asia are well known... they are different from other Asian terrains, first of all owing to the numerous geological and engineering studies and also from the results of the studies systematically carried out at the Institute of Hydrology and Engineering Geology of the Uzbek Academy of Sciences under the direction of G.A. Mavlyanov...”

Moreover, the particular importance of this area is connected to the fact that it was here that the ideas of Pavlov and Glinka were formulated, and Dokuchaev’s attitude was crystallized. Pavlov and Glinka and Dokuchaev were advocates of the so-called deluvial-proluvial theory of the origin of loess..."
Ecologists plot to turn the tide for shrinking lake

Qurban Sibtehmaner, Munich

The Aral Sea is dying. Researchers have given up hope that the central Asian lake — which was the fourth-largest in the world before intensive Soviet agriculture diverted the rivers that feed it — can ever be restored.

But a group of ecologists and economists is nonetheless proposing plans for a conservation strategy that could eventually reverse the ecological ruin of the region surrounding the shrinking lake. Germany and the United Nations Educational, Scientific and Cultural Organization (UNESCO) are backing the plan, for which scientific preparations could begin in Uzbekistan later this year.

Over the past half-century, the Aral Sea has lost four-fifths of its volume and more than half of its surface area as water from the Amu Darya and the Syr Darya, diverted to irrigate cotton fields in the surrounding region.

The shrinking of the lake has triggered an ecological disaster, with eutrophication of what is left of the lake's floor and heavy salination of the surrounding water table and soil, researchers say.

Intensive farming has also caused widespread pesticide contamination, according to scientists who have visited the region. Illnesses such as hepatitis, respiratory disease and anaemia are widespread, and shortages of food and drinking water are worsening, a crisis that has been compounded by the exceptionally dry winter of this year and last.

Now researchers at the Center for Development Research (ZEF) in Bonn are hoping to stop the rot by introducing sustainable patterns of land and water use to the region. They want to undertake a pilot scheme, after a preliminary investigation, to test the idea in the province of Khorezm, Uzbekistan. 400 kilometres south of the Aral.

Under the scheme, around one-fifth of the irrigated cotton fields in the area would be converted into forest or meadow. More efficient farming would enable the remaining area to yield the same amount of cotton, the project's architect says.

Christopher Martin, scientific coordinator of the project and an ecologist at the ZEF, thinks that local cotton growers can be persuaded to support the plan. "It is a legacy of Soviet times that most farmers in Uzbekistan have received solid scientific and agronomical training," he says. "Many of them have already signalled interest in participating."

The changes in land use would be accompanied by legal, administrative and economic reform, and its success will therefore require strong backing from the Uzbekistani government, which Martin also thinks will be forthcoming.

The idea hopes to protect the pilot by studying the ecology and economy of the region, including its hydrology, environment, demographics and agriculture. This study will take up to four years, says Martin, after which a pilot will be implemented on a single farm and then, perhaps, throughout the 6,300-sq-kilometre province.

The new strategy aims to mitigate the consequences of the changing environment, rather than trying to reverse the Aral Sea. A UNESCO report released last year said that there was no prospect of preventing the sea from drying up.

"Changing the behaviour of people and authorities will not be easy," says Paul Vila, one of the directors of the ZER. "We hope, however, that we will be able to demonstrate that, even in a crisis situation, it is sensible to think ecologically."

Local scientists from Tashkent State Agricultural University and Urgench State University will be involved in the project from the outset. If, as expected, the German science ministry approves a grant of 3 million euros (US$4.7 million) for the study phase, work on the project could begin next spring.

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http://www.dri.edu/DEES/INQUA2003/inqua_home.htm

XVI INQUA Congress

July 23 - 31, 2003
Reno Hilton Resort & Conference Center
Reno, Nevada USA

Welcome to the XVI INQUA Congress Web page. Held every four years, the INQUA Congress is the largest gathering of scientists studying the Quaternary period, the last 2.6 million years of Earth’s history. The theme for this Congress is “Shaping the Earth: A Quaternary Perspective.” INQUA will link with Geological Society of America (GSA) to provide management services including registration, abstract submission, and meeting services.

The main means of dissemination of information about the Congress will be via this web site and email. Delegates and potential attendees should bookmark this web site and submit an expression of interest via the Email Update link to remain in contact with the progress of this meeting organization and to receive updates via email. No printed circulars will be distributed.

Important Deadlines

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This special volume, concerned with Loess and Palaeosols: characteristics, stratigraphy, chronology and climate includes a selection of the 56 papers and 33 posters presented at “LOESSFEST 99”, an international conference held in the University of Bonn, 25 March - 1 April 1999. The meeting was held under the aegis of the International Union of Quaternary Research (the Commission on Loess) and the International Geological Co-Ordination Programme (Project 415—’Understanding Future Dryland Changes from Past Dynamics’).

It was Professor Ludwig Zöller of the Department of Geography in the University of Bonn who first suggested that a meeting might be held in the Rhine valley to celebrate the 175th anniversary of the first description of the Rhine loess at the locus classicus et typicus at Haardt (near Heidelberg) by Carl Caesar von Leonhard. The occasion of this suggestion was the ‘stock-taking’ meeting on Wind-blown Sediments in the Quaternary Record held in the University of London in January 1994 (Derbyshire, 1995a, b), and also sponsored by IGCP and INQUA. It was followed, in April 1994, by a NATO workshop on Genesis and Properties of Colluvial Soils held in the University of Loughborough, UK, to consider specifically the applied and geotechnical aspects of loess (Derbyshire et al., 1995). Actively encouraged by Professor Ian Smalley (then Secretary and now President of the INQUA Loess Commission), the writer had little trouble in persuading Professor Zöller to make up the three-man Organising Committee.

The agreed aim of the meeting was to provide an opportunity to review the current state and future directions of loess research. The plan was to meet about five years after the meetings in London and Loughborough, and to provide the opportunity to see in the field both classic and important recent exposures of the Rhine loess–palaeosol succession. There was a further reason why such a meeting was considered timely. This was the opportunity it would provide for the terrestrial loess community to confer with climatic modellers in the evaluation of existing information on terrestrial loess accumulations. The aim here was to establish a foundation for a data-base for loess fluxes in the Last Glacial Maximum. By the time of the Loessfest '99 meeting, this initiative had been named Dust Indicators and Records of Terrestrial and Marine Palaeoenvironments or ‘DIRTMAP’ (Kohfeld and Harrison, in press).

The collection of papers presented here illustrates very clearly the breadth of studies currently being undertaken on loess and the soils that develop upon it. The collection begins with two papers, the first on the nature of the silt particles making up the primary material of loess deposits and the second on the distinctive bulk behaviour properties of loess that make it such a hazardous surficial material. Wright reports on quartz silt generation using a series of laboratory simulations. She shows that both fluvial and aeolian systems are very profitable producers of quartz silt, thermogenic, periodic fluvial regime characteristic of many arid and semi-arid environments effecting considerable comminution. Potential sediment pathways in the formation of desert loess are considered, and this forms the basis of a proposed sequence of events to explain the loess deposits around the Sahara. It is concluded that silts sources and generation mechanisms are probably much more diverse in the case of desert loess than for glacial loess. The collapse of the engineering soil structure, and the associated mass failure of slopes in the thick loess of North China in terms of failure of the cementation bonds characteristic of much loess is next considered by Dijkstra. Although most of the physical properties of the loess in this large region show little variation, there are important variations in the modes of failure and collapse potential arising from varying thresholds of cementation bond failure and packing transformations. Dijkstra uses novel in situ tests, together with laboratory geotechnical methods, to show how these factors may enhance understanding of the slope instabilities mechanisms that trigger the often annual, catastrophic mass movements in the loess of a very highly populated region.

There follows half a dozen papers in which the dynamics and chronometry of the loess of Asia are central concerns. The first paper, by Graham, Ditchburn and Whitehead, describes important new Be isotope profiles of a 17m loess-palaeosol sequence near Wanganui, in New Zealand, that provide the first Southern Hemisphere comparison with data from the classic region of.
the Chinese Loess Plateau. This set of profiles, dating back to ca. 500 ka BP, offers new insights into the proven- cance and diagenetic history of the loess. The fact that the average 18O content in the New Zealand source is about double that found in the Chinese loess is explained by the higher mean rainfall, and the consequently higher 18O depletion flux in the New Zealand source area. A significant change for local palaeoclimates may be related to the warmer climate but not to the source areas of the Chinese loess. Comparison of a new magnetic record for North Africa with global proxy climate records by Dearing, Livingstone, Bateman and White also shows clear correlation with the loess–paleosol sequences in China, as well as the marine oxygen isotope (O1) record, for the OIS 8–5.5. They used coupled mineral magnetic measurements and a new chronostat based on luminescence dating to confirm the presence of at least four phases of pedogenesis during the period 100–250 ka in the loess–paleosol sequences on the Matmata Plateau, southern Tunisia. Preliminary at- tempts to infer paleoprecipitation levels from modern observations of soil magnetic properties suggest that, during the periods 100–120 ka and 200–2000 ka, precipitation was >400 mm a\(^{-1}\), compared with modern values of <150 mm a\(^{-1}\). Moving southwards, a study of the geomorphology of dated aeolian and fluvial sedi- ments in the northern Arabian Peninsula shows that both longer-term processes and the pollen and Maize shows that, between about 30 and 8 ka, several metres of loessic alluvium accumulated in valleys and depressions. Both locally produced weathering debris and allochthonous material were found in the central Namibian Desert and represents a more diverse and, in places, more humid climate than prevailed, with more intensive rainfall. It appears that the Early to Middle Holocene climatic change was not restricted to the N.W. Arabian region but represents a more complex pattern of environmental change across the whole of southwestern Africa.

Turning to the interpretation of late Quaternary tem- poral patterns of dust flux from the Asian mainland into the North Pacific, Nilson and Lehnhohl show, on the basis of a decade of records of dust on the ocean, that dust signals indicate three such patterns. They cast a critical eye upon the common assumption that an increase in dust accumulation is an indication of increased aridity in the Asian source region and that the dust signals may be related to a number of additional factors that may explain temporal and regional differ- ences in dust accumulation. These include eustatic expo- sure of the continental shelf and the effect upon the atmosphere of changing sea levels, i.e., variable fre- quency of meteorological situations conducive to long- range dust transport, variation in the strength of dust-laden winds, changes in the dust emission rate, and variations in dust-trapping vegetation cover. They conclude that simplified assumptions on the reasons for dust variability may lead to incomplete or even erro- neous palaeoclimatological conclusions. The theme of dust dynamics is continued in the paper by Kukla et al., using data on the Mongolian Plateau over the past 20 ka. Using sedimentary data, supported by 18O dates and some extrapolated ages for the sand-body sequences from the eastern Mongolian Plateau, Kukla is able to show that, in contrast to the marine OIS 3 paleosols (dated at 24,500, 28,500, 30,500, 34,400 yr BP) that formed under oxidizing conditions, two paleosols in OIS 2 (15,000 and 13,000 yr BP) and two Holocene paleosols (3350, 4700 yr BP) formed under reducing conditions. Conditions of either weaker winds or more abundant vegetation generally dominated the latter part of the last glacial (15,000–8000 yr BP), during which three paleosols (incipient hysteresis) were formed around 15,000, 13,000 and 8000 yr BP. Two con- clusions are reached. First, the northern boundary of the Gobi (stony desert) has retreated as many as nine times in the past 40,000 years (ca. 34,400, 30,500, 28,500, 24,500, 15,000, 13,000, 10,000, 6000 and 2000 yr BP). Second, in the light of the negative cor- relation between the susceptibility values and the silt contents and organic matter contents, it is proposed that the magnetic results of palaeoprecipitation hysteresis formation contrib- uted to the alteration of magnetic minerals from strong forms of oxidized iron to weak forms. Thus, the magnetic susceptibility signal is essentially an indic- ator of redox cycles. The less-well-documented topic of Late Holocene accumulation of loess dust is taken up by Rost in his description of soils in the Tuscany mainland of the Wutai Shan (2000–2400 m) in the Shanxi Province of North China. He shows that these silt-rich deposits, which are thought to be the result of increased aeolian activity, is not due to an increase in the content of aeolian dust sources in the N.W. Chinese deserts and changes in the downwind accumulation area provided by the mountain barrier of the Wutai Shan.

Concerning the Asian theme, the paper by Bäumler presents the results of a study of pedogenic processes in the development in aeolian deposits overlying moraines and landslide debris in the Khumbu Himal of eastern Nepal.
assemblages being very similar to those found in the loess. Fully developed woodland-macrocoenoses reflecting warm and humid climate characterize the interglacial, even in areas where such assemblages did not develop during the Postglacial. It is shown that, at higher elevations and in moister areas, different sediments, soils and molluscan assemblages existed at the same time. Their correlation with the loess sequences remains poorly documented because of a dearth of reliable fossil and stratigraphic evidence.

Three papers on the Carpathian Basin follow. The first, by Horváth, discusses the mineralogy and provenance of two middle Pleistocene (older) Bag Tephras and the Paksa Tephras in loess of Middle and Upper Pleistocene age in Hungary. Geochemical analysis suggests that the most likely origin of the Bag Tephras is the Roman or the Campanian volcanic fields in Italy. Similar geochemical investigation of the Paksa Tephras is still in hand, but preliminary results suggest the same sources. The highly contentious topic of the chronology of the older Hungarian loesses in general and the MB pedocomplex in particular is discussed. It is deduced that, in contrast to the matching of tephras horizons, the correlation of palaeohorizons is more complex, requiring time-consuming micromorphological analysis because of local effects on soil development and the weathering of tephras that are outcropping in the basin. Palaeoecological aspects of late Quaternary sedimentation in the Carpathian Basin are discussed by Stimege and Rudná in two related papers. The first reports the results of analyses of charcoal assemblages in loess from the Great Basin. On the basis of radiocarbon dating, it is shown that Picea-containing taiga forest-steppe habitats existed in this region between 29 and 21 ka BP. The forests were subject to extensive fires that appear to have affected the entire Basin. The direct dates (600–700°C) are consistent with natural forest fires. Detailed evidence shows that the burnt fragments are in situ and undisturbed by subsequent surface processes. Macroscopic charcoal remains and the molluscan fauna provide dating control and environmental information in a second paper concerned with changes in the ecology of this region. Two well-developed and one weakly developed charcoal layers are described as resting on top of palaeosols. The palaeosols that accumulated between 70,000 and 15,000 years BP. Palaeoecological analysis of the charcoal layers and Molluscs lead to the conclusion that recurring boreal forest steppe habitats characterized the Tertiary-Pleistocene-Boréal System mostly consisting of Picea trees in the north and Pinus sylvestris in the south, as well as six other arboreal species. Study of younger charcoal layers suggests that re-establishment of similar communities occurred every 2000–5000 years in response to fires, although densities may have varied. The time needed for the forest-steppe to redevelop remains to be determined.

A group of four papers provide new data and perspectives on the loess-palaeosol succession in Germany. Hilgers, Gerst, Janotta and Radkic apply luminescence (Th, Al) dating techniques to loess and palaeosol deposits to establish the age of the northern boundary of the Weichselian loess belt in northern Germany. It is known that the uppermost 2 m of the sediments accumulated in a glacial period towards the end of the Last Glacial and the early Holocene. The age span runs from ca. 8 until 15 ka with the averages concentrated at ca. 11 ka, regardless of the method or mineral fraction used. These data agree well with the results of oxygen isotope analysis of ice cores from Greenland (12.5 ± 1.5 ka). During this period, the transition from the Younger Dryas to the Preboreal, the climatic and environmental conditions favoured vigorous ecologic activity. Earlier suggestions that the northernmost loess deposits in Northern Germany represent the return of strong ice ages in conditions under the cold and dry conditions of the Late Glacial are thus confirmed. In their review of the Middle Rhine region, Boesingk and Frechen confirm that the loess-palaeosol sequences in these areas provide a relatively detailed and continuous terrestrial record of climate and environment change for the past 200,000 years. However, recent stratigraphic and chronologies of loess-palaeosol sequences in the Middle Rhine valley of Hilgers, Gerst, Janotta and Radkic and of the interglacial and glacial cycle is preserved in much more detail than has previously been recognized. In both sections, the last interglacial soil is covered by at least 10 palaeosols, post-dating the brown forest soil of the Eemian (OIS 5e). A high-resolution record of the last interglacial–glacial cycle in the Upper Rhine region of Germany provided by loess-palaeosol sequences at Nussloch is analysed by Antone, Möllers, Zoller, Lang, Minust, Hatté and Fontugne. Using samples at 10-cm intervals, this study highlights the response of the loess environment to global climatic variations during the last cycle. The basin soil complex shows a pedoecological evolution that indicates a clear transition towards increased continentality and decreased input of the Eemian (5d) and the beginning of the Pleniglacial. The Lower Pleniglacial was initially very arid with loess accumulation, followed by stratified loess-sand complexes. The Middle Pleniglacial complex (ca. 55–30) shows a dominance in loess sedimentation, with stable phases marked by Cambisols and tundra-gley. Organic soils in this intermediate phase (interstatal) yielded 13C dates of 32–33 ka BP. The boundary (ca. 23 ka BP) between the interstatal and the loess started to accumulate before the OIS 3/2 transition. Finally, a correlation of loess-palaeosol stratigraphy in Germany, Belgium and France, and spanning the whole of the last interglacial–glacial cycle, is presented in Grootes followed by discussion of the results of a study by Torbier, Appel, and Werner of a loess-palaeosol sequence from the last and the penultimate glacial–interglacial cycles in south-west Germany, using pedological, geochemical and rock magnetic methods. Problems of separating the influence of palaeo-relief, hydrology and climate complicate the interpretation, but their results show that even minimal degrees of soil formation may cause a distinct enhancement of the magnetic properties. Higher magnetic susceptibility (MS) values are found in the less-cemented parts of the palaeosols, while hydro-morphous processes operating on the ferrimagnetic minerals tend to lower the signal: both record past changes in the palaeoenvironment. Extremely low MS values characterise the reduced greyish zones of the interstatal. Other complications are introduced because MS may vary laterally along a horizon within a profile. Ferrimagnetic mineral concentrations are lower in illuvial horizons than in the loess, with higher values in illuvial horizons. It is concluded that palaeoclimatic interpretations based solely on MS should be treated with great caution. The last of the papers on the European region is an account of loess in southern Spain by Ginster, Skowronnek and Zöller. Samples from several sites that include Late Pleistocene loesses were analysed using palaeopedological methods. The resultant regional pedostratigraphy is a high-resolution indicator of changing climate during the last interglacial/glacial cycle in the Western Mediterranean. In general, it appears that these chronologies show some similarities to the Middle European loess stratigraphy. It is inferred that the Late Pleistocene sequence, even in this sub-humid to semi-arid region of southern Spain conforms with the general model for western Europe, with loess accumulation in relictual zones (adjacent) and soil formation in wetter (interstatal) conditions.

The last paper in this volume, by Sayago, Collantes, Karlson and Sanabria, presents an overview of the genesis and distribution of the Late Pleistocene and Holocene loesses of Argentina, with special reference to the loesses in the northern, sub-tropical region. Regional factors are shown to be very important in explaining loess distribution, taking into account the SWE and other factors that affect the transport path throughout Argentina. The available dating confirms the age of the superficial loesses as Pleistocene and Holocene. It is suggested that the Late Pleistocene loesses depositional episodes match the highest dust concentrations found in the ice core records at both poles. The prominent influence of volcanic materials, affecting not only the loess mineral composition but also the genesis and evolution of the loess-palaeosol sequence, is emphasised. Finally, the importance of the palaeosols as indicators of palaeoenvironmental conditions is clearly demonstrated by descriptions of outcrops in the pre-Andean valleys of north-western Argentina.
4. A Brief Summary of Midecontinental North American Loess

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Loess of late Quaternary age is abundant in the central part of North America, found mainly in a broad, 1500 km-long east-west belt in the states of Ohio, Indiana, Illinois, Iowa, Nebraska and Colorado and a narrow, 1500 km north-south belt extending from Wisconsin to Louisiana. Loess is the most important parent material for agricultural soils in the United States.

Loesses deposited prior to the last glacial period are known to exist in the entire region. The oldest of these that is dated is the Loveland Loess, which, based on direct TL dating of the loess itself, is about 120,000 to 160,000 years old, and apparently correlates with the penultimate glaciation, or oxygen isotope stage 6. A well morphologically well expressed palaeosol called the Sangamon soil is developed in this loess and apparently dates to the last interglacial period, equivalent to oxygen isotope stage 5 (or the Eemian interglacial in European terminology) and probably also part of stage 4. The youngest pre-last-glacial loess, found east of the Mississippi River, is called the Roxana Silt, and dates to sometime in the interval between ~50,000 and ~30,000 yr BP, based on radiocarbon and TL methods, equivalent to some or all of isotope stage 3. An equivalent unit called the Gilman Canyon Formation is found west of the Mississippi River.

Most studies over the past 50 years have focused on loess of the last glacial period, referred to as the Peoria Loess. It is a massive silt loam that is as thick as 50 m in parts of western Nebraska, as thick as 40 m in western Iowa (east of the Missouri River), and as thick as 20 m to the east of the Mississippi River in Illinois. Despite the apparent presence of a continuous blanket over the mid-continent region, Peoria Loess composition is not spatially uniform. East of the Mississippi River, carbonate content of loess is higher, reflected in higher abundances of CaO and MgO. West of the Mississippi River, particularly in Nebraska and Colorado, loess is lower in carbonates, but higher in K-bearing minerals and plagioclase, reflected in higher K2O and Na2O contents. Clay mineral content is also higher in loess of the western part of the region, reflected in higher Al2O3 and Fe2O3 contents.

Peoria Loess composition at a given site also varies as a function of age/depth. For example, a thick loess section in western Iowa has low carbonate content in its lower 10 m, probably reflecting syndepositional leaching during slow loess accumulation. The 10 m above this zone have carbonates, but relatively low fine silt and clay contents, reflected in relatively low Al2O3 and Fe2O3 contents. The uppermost 20 m of the section are also calcareous, but much higher in clay and fine silt, reflected also in relatively high Al2O3 and Fe2O3 contents. The changes in particle size in this section are interpreted to reflect a shift from an exclusively local source (the Missouri River) to a local source augmented by far-travelled, fine-grained loess derived from western sources. Although there have been few studies of this detail, they indicate that a simple picture of a spatially and temporally uniform sediment blanket is probably not realistic for the region.

Radiocarbon ages of Peoria Loess show that loess deposition, while occurring broadly within the last glacial period, did not take place at the same time everywhere. Maximum-limiting radiocarbon ages (of organic matter in a soil formed in the uppermost Roxana Silt and the Gilman Canyon Formation) are as old as 30,000 to 34,000 years in some places and as young as 20,000 to 22,000 years in other places. Minimum-limiting ages are much more difficult to obtain and are based mainly on snails found in the upper part of the loess in areas east of the Mississippi River and on organic matter in a soil that separates Peoria Loess from an overlying Holocene loess further west. These minimum-limiting ages range from about 10,000 to 12,000 years. Rare occurrences of charcoal or spruce needles in the lower and middle parts of Peoria Loess yield radiocarbon ages of 12,000 to 20,000 years.

analyses of Peoria Loess have mostly yielded ages of about 17,000 to 24,000 calendar years BP.

Numerous studies, dating back to the 1940s, have shown that Peoria Loess shows considerable variability in particle size away from river valleys that were major outwash-bearing valley trains from the Laurentide ice sheet during the last glacial period. With increasing distance east of the Missouri, Mississippi, Wabash and Ohio Rivers, Peoria Loess is thinner, lower in sand and coarse silt, higher in fine silt and clay, and lower in carbonates. Decreasing thickness reflects a decreasing supply of sediment away from a source whereas the increase in fine particles reflects the winnowing of coarse particles away from that source. The decrease in carbonate content reflects syndepositional weathering away from the source where sedimentation rates are lower.

Despite the obvious link to glacial outwash sources in Indiana, Illinois, Wisconsin, and Iowa, loess found to the west of these states, in Nebraska, Kansas, and Colorado, seems to be unrelated to sediment derived from the Laurentide ice sheet. Drainages adjacent to loess in this part of the region (the Great Plains) have headwaters that were not fed by meltwaters of the ice sheet during the last glaciation. Although meltwaters from much small glaciers in the Rocky Mountains fed Great Plains rivers during the last glaciation, it is unlikely that this was the major supply of silt to the region; Rocky Mountain glaciers were relatively small, but loess in Nebraska is as thick as 50 m. Isotopic studies (Pb isotopes in foraminifera and U-Pb ages of zircons) have shown that loess in eastern Colorado is partly derived from non-glacial source and loess in Nebraska is mostly derived from the same non-glacial source. This previously unsuspected parent sediment is volcaniclastic siltstone of the Tertiary White River Formation, which is exposed over large areas of the central Great Plains, to the north and northwest of the loess belt.

There are at least five major issues regarding Peoria Loess, all-important to climate modeling efforts, that need to be addressed in future studies. (1) It is not known why Peoria Loess is so much thicker than all pre-Peoria loesses, including those that date to major glaciations, such as the Loveland Loess of the penultimate glaciation. (2) It is not known how much of Peoria Loess in glacial terrain is not glaciogenic, but derived from far-travelled non-glacial sources now confirmed to exist in the central Great Plains. Continued isotopic studies of different size fractions could possibly answer this question. (3) Because mainly bracketing radiocarbon ages are the age control on Peoria Loess, it is not known what the variability in sedimentation rate within the last glacial period might have been, i.e., did sedimentation occur mainly in the early part of the last glacial period, at the last glacial maximum or during deglacial time. Detailed, high-precision OSL dating could answer this question. (4) The spatial trends in loess thickness, particle size, and carbonate content, as well as isotopic identification of non-glacial loess sources in the central Great Plains, all indicate that last-glacial palaeowinds were likely from the west or northwest. This observation is in conflict with both AGCM results, which show dominantly northerly or northeasterly winds due to the presence of a strong glacial anticyclone over the Laurentide ice sheet. Studies of modern loess deposition in periglacial regions could possibly address this question if seasonally variable winds are responsible for the difference between the observed and modelled palaeowinds. (5) The identification of non-glacial loess sources in the Great Plains region is in conflict with simulation of last-glacial dust sources, using a linked AGCM-biome-biogeoechemical model. The amount of dust/loess generated from this source far exceeds that recorded by other source areas of North America (Alaska, southwestern USA, Mexico) that were simulated by this model.
5. Loess-Palaeosol Records in Siberia

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General Background

Loess and loess-like deposits in Siberia are distributed mainly in the southern part of the territory (between 50° and 59° N latitude and 66° and 97° E longitude), covering a broad geographical area ca 1500 km wide (from north to south) of about 800,000 km² between the Ob and Angara River basins north of the Altay and Sayan Mountains. They represent a continuation of the Eurasian loess belt spanning from Western Europe across the Russian Plains to the north-central China Loess Plateau. The Siberian loess ranges in thickness from a few metres in the Angara River valley and the Lake Baykal basin in the east to up to 40 m in the Yenisei River valley in the southern Central Siberia, and reaching up to 150 m on the Priobie loess plateau in the west. The loess sections are locally intercalated with other aeolian, alluvial, and colluvial deposits (sands, silts, and clays), and interstratified with variously developed paleosols, documenting a complex nature of the Pleistocene environments.

The Siberian loess record spans throughout the Quaternary Period, yet it is locally rather fragmentary or completely absent for the earlier stages (mainly preserved on the Ob Plateau and in the Kuzbas Basin in the western and central part of the territory, respectively). The most complete and nearly continuous sections date to the Late Pleistocene (the Yenisei area). The present climate is strongly continental with cold and dry winters with little snow cover, and warm to hot summers with mean annual temperature of ~0.5 to ~2 °C.

Current studies

The Siberian loess has been studied in detail during the last several years following the previous field investigations and chronostratigraphic interpretations made by Russian colleagues (e.g., Zykina et al., 1981). The principle Late Quaternary chronostratigraphic system follows the scheme subdividing the Late Pleistocene into four climatic stages (the Kazantsevo Interglacial, the Zyryanka Glacial, the Karga Interstadial and the Sartan Glaciation), corresponding to Oxygen Isotope Stage (OIS) 5-2.

The major focus of the present studies is 1) the stratigraphy of long-term subaerial records in south-western Siberia (Zykina, 1999), 2) the high-resolution Late Pleistocene climatic records and related palaeoenvironmental evolution of landscape and biota (Chlachula et al., 1997, 1998), and 3) a chronological refinement of the loess archives for the last 130 ka by TL and OSL dating in central southern Siberia (Frechen and Yannikikh, 1999).

A particular attention is paid to the loess deposits in the upper Yenisey River valley, comprising the most complete record to date in this part of northern Eurasia for the last two glacial-interglacial cycles (Chlachula, 1999). A total of 32 pedogenic horizons from the OIS 7-1 time interval have been previously recognized in the area (Chlachula et al., 1997). The local loess mineralogy is characterised by quartz (54-72%), and feldspar (10-21%), calcite (4-7%), chlorite (3-6%), biotite (2-3%) and other minerals. The mineralogical composition and the fresh surface morphology of the fine silt fraction indicate a local provenance of the sediment, although most of loess in southern Siberia is assumed to have been derived from the ice-sheet from the north.

Study methods and approaches

The present complex investigations are aimed at specifying the nature and rate of loess sedimentation and the subsequent pedogenic modification and to reconstruct environmental conditions prior to, during, and after formation of the fossil soils. The principal study aspects used as indicators of the past climatic change in the fossil palaeosol horizons are the TOC and CaCO₃ content; grain size and mineralogy of the sedimentary matrix; fossil periglacial features (solfaturation, cryoturbation, frost wedge casts); and magnetic susceptibility.

Particular attention has been paid to magnetic susceptibility, low-frequency (LF) and frequency-dependent (FDF) sensitivity, as this has proven to be a reliable indicator of the past climatic change in the larger study area (Chlachula et al., 1997, 1998; Chlachula, 1999). The relationship between the climatic change and magnetic susceptibility fluctuation is clearly evident, with the LF susceptibility maxima corresponding to the intervals of the most intensive loess deposition and the minima correlating with the most developed chernozemic palaeosols. An intense wind activity leading to accumulation of greater quantities of larger ferrimagnetic (mainly magnetic) grains is believed to account for the magnetic susceptibility increase during cold (stadial) intervals (Chlachula et al., 1998). A similar pattern has been observed in loess in southwestern Siberia (the Ob Plateau). The total magnetic susceptibility capacity of palaeosol horizons is clearly not a function of weathering intensity and time, as in Europe or China, but depends on a priori upon the quantity and quality of primary magnetic minerals within the unaltered parent material inherited from original geological sources. Magnetic susceptibility, coupled with other palaeoclimatic proxy data, has proven to be a very sensitive indicator of the past climate change in the broader area.

Late Pleistocene loess-palaeosol records

A series of high resolution loess-palaeosol sections has been investigated in the Ob, Yenisei and Angara River basins as a part of the 1500 km W-E continental transect project in 1997-1999, with a principal focus on the last interglacial (OIS 5, sensu lato). The results show patterned climatic variations and uniformity of natural environments across the south Siberian territory during the Late Pleistocene (Chlachula and Kemp, in prep). The key Late Quaternary records from the Northern Mchninsk Basin in the southern Kraysnoyarsk region (Kurtak sections 29 and 33) and the southern Priobie loess plateau north of the Altay Mountains (Biysk and Iskitim sections) provide evidence for a strongly fluctuating climatic change in this part of Eurasia during the Late Quaternary. Magnetic susceptibility (low frequency and FDF) records, with maximum deviation amplitudes between 130 and 10 ka BP, together with other palaeoenvironmental proxy data (grain size, %CaCO₃ and %organic carbon variations) show a globally diagnostic trend for the last glacial-interglacial cycle.

The last interglacial (sensu lato) includes several warm as well a very cold stages (correlated with OIS 5e-5a). A strongly continental warm climate culminating around the peak of the last interglacial (OIS 5e) is followed by a gradual shift to more humid and cooler conditions during the subsequent interstadial stages (OIS 5c and 5a). The cold substage 5d is documented by up to 1.5 m deep frost wedge casts dissecting the OIS 5e chernozem (TL dated to 125 ka), indicating a dramatic decrease of temperature and humidity, and establishment of a cold tundra environment. This evidence corroborates with the data from the Lake Baykal (Karabanov et al., 1998) suggesting an intense glaciation in Siberia during the last interglacial. Following this time interval, the climate in southern Siberia became more pronounced with very cold and dry stadials during the last glacial stages (OIS 4 and 2) interspersed with moderate mid-late glacial (OIS 3) interstadials.

Past climate change and natural environments

The past climatic variations are well monitored in the stratigraphic loess record indicating a similarity of natural environments in the steppe-parkland zone across southern Siberia. The
initial pedogenic alteration of parent material is expressed by incipient gleying in a cold, humid environment within a seasonally waterlogged setting and a cold periglacial tundra. A progressive leaching of calcium carbonate from the loessic stratigraphic unit is accompanied by organic matter accumulation reflecting a gradual increase of summer temperatures and surface stability that contributed both to prolonged weathering processes and formation of brown (forest-tundra) soils, and, under warmer conditions, of chernozemic (parkland-steppe) soils. An analogous pattern is documented in the Late Pleistocene loess sections in western Siberia (Zykina, 1999), with reactivated soil formation processes during surface stabilisation under warmer conditions and subsequent solifluction and cryoturbation due to climatic cooling and increased humidity.

Summary and conclusion

With respect to the mid-continental geographical location with largely reduced atmospheric effects of the world's oceans, the Siberian loess – palaeosol records are of major importance for mapping the Quaternary climatic and environmental change in central Eurasia and the principle mechanisms behind the process. Due to the pronounced climatic continentality and topographical isolation between the Central Asian mountain systems in the south and the Arctic Ocean in the north, the Siberian loess deposits provide an excellent source of high-resolution palaeoclimatic data for the regional, as well as global, significance. Particularly the Late Pleistocene (OIS 5–2) loess archives have a key relevance for establishment of the close correlation framework between the European, Central Asian and Chinese loess-palaeosol records within the major W-E continental transect, and represent a significant source of proxy data for reconstruction of past climates and climate change in the Northern Hemisphere.

References


6. Loess from South America

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Distribution and age

The distribution of loess in southern South America covers most of the Chaco-Pampas plain of Argentina (Bolivia and Paraguay) and small areas of the western mountain environments. Loess was also reported in neighboring areas of Uruguay and southern Brazil. Teruggi (1957) mapped the distribution of loess deposits (worked loess and loess-like sediments), indicating that secondary loess was even more abundant than primary loess. Still the distinction between primary and secondary loess constitutes a major topic of discussion.

The beginning of the loessoid sedimentation cycle has been related to a phase of Andean orogeny that resulted in the elevation of the Andes Cordillera in the late Miocene (circa 10 Ma) which acted as a barrier to moisture laden Pacific winds. This initiated "the desertification of Patagonia caused by the rain shadow while precocious Pampas environments probably came into prominence at about this time" (Patterson and Pascual, 1972 in Marshall et al., 1983). The late Tertiary deposits as well as the Quaternary loess material, are mainly composed of volcaniclastic fine sandy silt, mostly modified by pedogenesis and reworked by aqueous transport agents. The scarcity of primary aeolian facies is attributed to their low preservation potential in the sedimentary record.

Stratigraphically, although the late Cainozoic loessoid complex was grouped under several different names, Pampuan Formation (and informally Pampuan sediments) is the most commonly used as a collective term including both Tertiary and Quaternary deposits. The two most important type sections are the Mar del Plata sea-cliffs and the Paraná river bankfulls. The classical concepts on the origin of Argentine loess are mostly based on the grain size and mineralogical analysis of samples from the Mar del Plata type section (Teruggi, 1957). Later, this study was extrapolated to the rest of the Chaco-pampes plains, resulting in an oversimplified model of the Argentine loess record.

The regional loess record

During the last twenty years a renewed interest on the Quaternary, brought about several studies on palaeomagnetism, sedimentsology, vertebrate palaeontology, palaeopedology, palynology and stratigraphy in different areas of the Pampas (Mar del Plata, northern Buenos Aires, south central Santa Fé, west central Córdoba) and NG Argentina (Tucumán). Although significant results were obtained the timing and climatic significance of the loess record is still difficult to interpret and correlate within the region because of the different methodological approaches followed and the lack of integration between the studies.

The Mar del Plata-Miramar type section (38° 10'S, 57° 40' W) consists of loess-like sediments reworked by fluvial streams and slopeswash while primary loess facies are minor sedimentary components. The late Pliocene to Late Pleistocene-Holocene record is continuously exposed with a thickness of 20-30 mts along 35 km of sea-cliffs. The sedimentation was discontinuous including important hiatuses. Lithostratigraphic, pedostratigraphic, biostratigraphic (vertebrate palaeontology) and magnetostratigraphic studies were performed. Pedogenesis deeply modified the deposits with fluvial activity (both invertebrates and vertebrates) playing a significant role in the reorganisation of the original material. The age control is mostly based on vertebrate assemblages (land-mammal ages, stage-ages) (Tonni et al., 1992) and magnetostatigraphy (Ortega y Valenciano, 1984, Ruocco 1980, Ortega, 1988). Numerical ages were recently obtained (Schultz et al., 1998). This
section is particularly important to study the Pliocene-early Pleistocene interval consisting of a 20-m thick sequence of loess–(loessoid)-palaeosols. In the Mar del Plata-Bahia Blanca area (33°30’-3°30’; 58°-60°W) several studies on grain size, mineralogy, 14C (among others, Zárate & Blasi, 1993, Bideri, 1996) and palynology (Prieto, 1996) were conducted on the late Pliocene-Holocene record (sandey loess, loessial sands).

The northern Pampas of Buenos Aires (33°45’-3°50’; 55°-58°W - 59°-30’W) is a type area of the Pampean Formation where classical studies on the stratigraphy and palaeontology of the Pampean loess were performed (Ameghino, 1889, González Bonorino, 1965). Since 1985, several sections have been the focus of analysis on palaeopedology (Teruggi & Imbellone, 1987, Imbellone & Teruggi, 1993; Zárate et al. in press), palaeomagnetic studies (Bobbio et al., 1986, Nabel et al. 1999, Bidegain, 1998), environmental magnetism (Orgeira et al., 1999, Nabel et al. 1999), geochemical analysis (Gale et al., 1998; Morais, 1999) and vertebrate palaeontology (Tonti et al., 1999). General information on the grain size, mineralogical composition and chemical composition (carbonate, organic matter) is available. Following general models, loess was attributed to arid conditions and palaeosols to more humid and warmer conditions (Tonti et al., 1999). The age control is based on magnetostratigraphy and vertebrate palaeontology. Still, the correlation with deep-sea cores is not possible.

South central Santa Fé (32°30’-33°59’; 59°45’W - 61°45’W) and also the eastern part of Cordoba

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～0.0524(C%),而且黄土层中这种有机质与红褐
色古土壤层差异不大。经探剖表明黄土与部分黄土层
中多为钙化植物，因此其组成中有机质含量不
足1%。黄土层中钙含量较高，而且马兰黄土以
及其它黄土中钙含量较低，红褐色古土壤中钙
量中等，钙含量中等。证明古土壤发育时的生物产
生了相当数量的有机酸。

黄土中的有机物在土壤剖面分布具有均一性，而
且可以指示黄土是成土过程中的植被发育的古
土壤。

黄土中的有机物同样也是黄土形成时的原始
物，有机物积累在原生层剖面中。而黄土中有机物
的形成过程是由于长期的、连续的成土过程中的
作用。由于黄土的成土过程是由于长期的、连续的成
土过程中的作用，因此可以指示黄土是成土过程
中的古土壤。

2 黄土形成与演变

黄土形成过程中及其继续演化过程对土壤形成
的认识。一般认为黄土形成过程是风尘堆积物在
原生层剖面中，受到风化和生物作用的影响，不
同程度受到风化作用的影响，风化作用影响
范围广泛，结果在很多地方形成风化壳。

黄土中钙含量高，有机质含量低，是一种氧化
物和铁的氧化物，其主要成分是氧化钙和铁的氧化
物，占黄土中氧化物的90%以上。黄土中氧化钙含
量高，且以碳酸钙形式存在，形成土壤学上所称的
碳酸钙。

在黄土层中，CaCO₃主要以石膏、假晶、薄带形式存在，是成土
过程中形成的产物。在低氧条件下，CaCO₃易被氧化，形成
碳酸钙。

黄土中CaCO₃的存在形式有多种，主要为生石灰和熟石灰。
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3. 黄土地层气候划分

过去认为黄土地层中发现了37层红棕色土层。根据一些地区的调查研究，黄土地层包括了42层黄土和41层红棕色土层。虽然考虑到了第1、2层、3层、5层红棕色土层的复合以及第1、6、7、9层黄土与中生代的红棕色土层的差异，但是黄土地层的划分仍然存在争议。黄土地层的划分可以作为研究气候变化的工具。根据黄土地层的划分，可以将其划分为10个阶段，每个阶段又可以划分为10个亚段。

表1：

<table>
<thead>
<tr>
<th>地区</th>
<th>比较者</th>
<th>年代（年）</th>
<th>2.5Ma</th>
<th>0.73</th>
<th>0.128</th>
<th>0.28</th>
<th>0.01</th>
<th>0.01</th>
</tr>
</thead>
<tbody>
<tr>
<td>中国</td>
<td></td>
<td>59</td>
<td>26</td>
<td>10</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

在2.5Ma以来的气候周期中，可以分析出100个阶段，每个阶段可以进一步划分为10个亚段。黄土地层的划分可以作为研究气候变化的工具。根据黄土地层的划分，可以将其划分为10个阶段，每个阶段又可以划分为10个亚段。

4. 结论

综上所述，可得出如下认识：（1）黄土地层具有明显的气候变化趋势，黄土地层的划分可以作为研究气候变化的工具。根据黄土地层的划分，可以将其划分为10个阶段，每个阶段又可以划分为10个亚段。

关键词：黄土地层；过程形成；灰色-棕褐色粘土环境。

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Abstract

There are soil macrostructure in loess, such as similar prismy structure, lump structure, granular structure, root holes, and microstructure, such as optically oriented clay film developed in stronger soil formation processes. Loess is rich in CaCO₃, but it is mainly secondary and is the illuvial products formed by dissolving and depositing of CaCO₃ and is a sign of illuvial layer of CaCO₃. These characteristics show that loess experienced soil formation processes. The fossil animals, such as snails, and a lot of root holes also indicate that the loess formed in soil formation processes. The developmental process of loess was longer than that of mollusks, the reasons why it didn’t change into red-brown paleosols were cold and arid climate and the features of the soil formation processes. The soil profile of loess is not clear, which results from continual dust deposition and CaCO₃ illuviation. Loess developed mainly in steppe, desert-steppe and forest-steppe areas, the loess in different areas and different characteristic is mainly Siercens, Chreast, Brown Soil, Brown Desert Soils and Loessial Soils.

Soil formation mainly includes weathering, migrating and illuviating of CaCO₃ as well as weak biological action in desert-steppe. CaCO₃ exists in the form of powder and spots and CaSO₄ sometimes occurs in the areas where soil structure develops poorly and root holes and insect holes are a few. The obvious migrating and illuviating of CaCO₃ and forming of biological structure are the dominant processes in which loess develops in steppe areas. CaCO₃ exists in the form of film and soil structure, such as granular structure and root holes, is obvious in the areas. Besides notable migrating and illuviating of CaCO₃ as well as forming of biological structure, clay grouting sometimes occurs in forest-steppe areas in the formation process of loess. CaCO₃ nodules occur often, granular, lumpy, similar prismy structure and root holes developed well, and organic substance is high in content and optically oriented clay film sometimes can be seen in the areas.

Grey-yellow loess that is the paleosol can be used as a mark in reconstructing paleoclimate. According to the alternation of loess and paleosol, the biological, soil and climatic changes since 2.5Ma can be classified into 101 stages consisting 51 cycles and sub-cycles.

Key words: essence of processes; forming layers; grey-yellow paleosols; environment.