LL welcomes to Loughborough all participants in the NATO Advanced Research Workshop on The Genesis and Properties of Collapsible Soils'. Loess is, of course, the chief and most important collapsible soil and has long been investigated by members of the INQUA Loess Commission. We hope that the fruitful discussions will reveal many new aspects of the collapse problem. The Loess Commission has been involved in two conferences in the UK in the early part of 1994 which largely span the current large range of topics being investigated in the loess-rich parts of the world. In January 1994 at Royal Holloway, University of London, there was the joint QRA/INQUA meeting on 'Wind Blown Sediments in the Quaternary Record' which was mostly concerned with loess stratigraphy and dating. Read a full account in the QRA Newsletter for February 1994. In April 1994 at Loughborough University of Technology we have a complementary meeting which involves geotechnical loess problems, the most important of which is collapse. This issue of LL looks, as always, at all aspects of loess, and we reprint some abstracts from the Royal Holloway meeting.

Loess Letter LL is the newsletter of the Loess Commission of the International Union for Quaternary Research INQUA. It is published twice a year (usually in April and October) by Jan Smalley and Tom Dijkstra, Civil Engineering Department, Loughborough University of Technology, Loughborough, LE11 3TU, UK: Fax 0509-610231. Major decisions relating to the Loess Commission are made at the main INQUA Congresses; the next Congress - the 14th - will be held in Berlin in August 1995, details from your national Quaternary Committee or from Prof Dr M. Böse, INQUA Büro, Grunewaldstr 35, D-12165 Berlin; Fax (49) 30 838 6532. The Loess Commission aims, briefly stated, is to encourage interest in, and research on, loess, and to facilitate links and communication between loess investigators. To celebrate the Berlin Congress, LLS 31, 32 and 33 carry an additional title: 'Loess Briefs' - which means 'unofficial loess letters'. The main Berlin loess event should be a symposium on 'Losen in der Gegenwart' to celebrate the (more or less) 60th Anniversary of Rudolf Grahn's map of the distribution of loess in Europe. We hope to discuss all aspects of European loess, but an emphasis on distribution might be contrived. Contributions on loess from any part of the world will be welcome for the Congress in general.

LL31 contains some samplings from papers in the new book on 'Engineering Characteristics of Arid Soils' edited by B. Fookes and R. Parry (Balkema 1994) and a few abstracts from the QRA/INQUA meeting in January. The cover comes from a paper by Alena Klukanova and shows an idealised loess soil structure.

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**Geomorphic features and evolution of the submerged delta of the modern Yellow River**

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Language: CHINESE

The Yellow River Delta is formed as a result of the accumulation of sediment transported by Yellow River from the Loess Plateau. Morphological features of the submerged Yellow River Delta are divided into the following types: delta front (consisting of mouth bar and distal bar), prodelta and mud bay. The mouth bar is the growing point of the Yellow River Delta. Its stability has a direct effect on stability of the river mouth and life-time of the channel. River mouth can push aside sea water, flow 8-10 km into the sea from river mouth and form scour structure on the sea bottom during the flood period. Data of geomorphological evolution indicate that the lateral distance of transported silt is 16-20 km in width. From English summary.
Classification of arid soils for specific purposes

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ABSTRACT
Engineering structures can be classified according to their purpose, and the requirements of the soil on which, in which, adjacent to which or from which the structure is constructed can be specified. This would form the basis of an application - orientated approach to classification. A second approach is a material-orientated approach to classification, according to which both the physical properties and the local environment should be considered before the material can be classified as suitable for a particular purpose. Examples of the two approaches are given. It is clear that the material approach is most complex, and yet it follows the paths of thought that an engineer would need to follow and it thus provides the basis of a knowledge-based system for design.

INTRODUCTION
The range of engineering structures to be designed, each with proper attention to soil structure interaction, is immense (Aitchison 1983). A few examples can be given here, within four basic categories:

1. Upon the soil: there are road, airfield and railroad pavements; buildings (domestic, institutional and industrial) with shallow or deep footings; embankments and dams.

2. Within the soil: there are tunnels and conduits (for transport or for location of services); open excavations (drainage ditches, open cast mines, etc); basements and underground structures (car parks, etc).

3. Construction with (or of) soil: relates to earth dams (for the retention of water or other fluids or semi-fluids); embankments (terrain modification for road or rail systems, etc); fills (reclaimed areas, etc).

4. Construction problems from adjacent soils: relates to

Figure 3. Loess classification
Collapse of soil structure

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INTRODUCTION

The origin of arid soils is bounded with three principal factors: climate, parent material and local conditions (geography, morphology, etc.). Since climate and local conditions are time-variable, paleoarid soils may be encountered produced under favourable conditions in the past which do not persist. An example of such a soil is represented by loess, soil of eolian origin coming from the arid interglacials of Quaternary period. Though arid soils form a special group of soils, their behaviour should follow the same pattern like any other soil but with some specific features. One of the most prominent one is the bonding of arid soils with cementation bonds as accentuated with evaporites. Casagrande (1932) already attracted the attention to bonding and its importance has been emphasized recently (Lecouël and Vaughan, 1990). By analyzing the bonding of arid soils - the writer chose loess as a fitting example - one can better understand the process of debonding of common soils (bonded soils are often called "structured" and debonded "destructured"). As far as the soil structure is concerned, one may differentiate bonding within the aggregates or particle clusters (intragranular bonding) and mutual bonding between aggregates (intergranular bonding - Feda, 1982), the latter being, as a rule, weaker.

COLLAPSE ON WETTING

The writer's starting point is the collapse of loess structure on wetting. It is well known that such a collapse is not confined to loess (Feda, 1966) but loess represents a suitable model material for dealing with it. There are two critical conditions for a loess to be collapsible: high porosity (>40%) and low degree of saturation (<60%). The ratio of the additional compression due to wetting

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to the specimen's height $\Delta e/(1-\varepsilon)$ ($\varepsilon$ means void ratio) is
called the coefficient of collapsibility $i$ (in %). Fig. 1 shows two
typical test series (1, 2) demonstrating the depend-
ence of $i$ on the axial (osmometric)
pressure $\sigma$. The local vari-
ability of $i$ can be con-
siderable. Curve 1 and open
circles denote the same material
(loess from Praha-Dejvice) and
in the same locality some loess
strata are even uncollapsible
having lost their structural
metastability through transport by solifluction. According to Fig. 1 the
metastable (collapsible) structure transforms into the stable one either
by the virulent collapse on wetting or - retaining its original water
content - by the elevated pressure (for loess in Fig. 1 at $\sigma > 0.6$ MPa).

Fig. 2 depicts two oedometric com-
pression curves (loess from Praha-
Sedlec), that of the very dry un-
disturbed loess (water content of
about 10% - 1 on Fig. 2) and
another after the water inundation of the same loess (curve 2). Both
curves are extrapolated beyond $\sigma$,
= 2 MPa which was the maximum ex-
perimental pressure available. The
value of $i$ (Fig. 3) confirms 1 and 2
in Fig. 1. In a broader diapason. At
higher pressures ($\sigma > 5$ MPa),
the dotted lines in Figs. 2 and 3
seem to be more probable.

**PROGRESSIVE COLLAPSE BY STRAINING**

As with loess, two compression curves (undisturbed and debonded) are
needed to define the extent of debonding of other soils, analogous to $i$. They
may be found already with Casagrande (1932 - Leda clay). Fig. 4 presents a
more recent example (Bothkennar clay - Burland, 1990). Many similar curves
can be found in the literature. They show that the
value of $i$ rises to some maximum (structural resist-
ance or strength, marked eg by the preconsolidation load) and then gradually $i$
. 0 as the undisturbed com-
pression curve approaches the reconstituted one. The

**CONCLUSION**

Generalizing the above phenomena, one may classify the various processes of debonding into:

- Total collapse of structural bonds by external factors (water, quake) - Fig. 6a. All bonds are broken down more or less simultaneously. Typical representatives are collapsible arid soils.
- Progressive debonding (by straining, time, gradual loading),
  affected by series of local collapses - Fig. 6b. It is the result of nonhomogeneous stress- and strain fields and/or varying resistances of individual bonds.
- Mixed process where an initial intensive collapse is followed
  by progressive debonding - Fig. 6c. The gradual attenuation of debonding
  with rising load is typical, on contrary to the total collapse.

Since debonding of the soil structure means the decrease of the soil
rigidity and strength, the practical significance of these studies is
apparent.

**Figure 6 Classification of various forms of structural debonding.**

- **COLLAPSE**
- **PROGRESSIVE DEBONDING**
- **MIXED PROCESS**

**Figure 4 Compression curves (oedometer) of Bothkennar clay (Burland, 1990).**

**Figure 5 Characteristics of progressive debonding of Bothkennar clay (Fig. 4) and Dejvice loess (Fig. 1, curve 4).**

**Figure 3 Coefficient of collapsibility vs stress as deduced from Fig. 2.**
REFERENCES


Fig.8. Collapse test results on loess samples reported by Erol and El-Ruwaith (1982)

as the construction material for a large part of the
dam. Penman (1987) provides some useful data relating to the
large loess core. The volume of the core fill was 3,965,466m³,
which was more than half the volume of the dam. Average
placement water content was 18.6%, that is 1.3% on the dry side
of optimum, and the average dry density was 15.6 kN/m³.
Average specific gravity of the silt was 2.62, so that the
average void ratio would be 0.646 (water void 0.487 and air
void 0.158) with a degree of saturation of 75%. The average

bulk density (18.5 kN/m³) was not particularly high considering
that compaction was by 12 passes of a 6t/m sheepsfoot roller on
every 150mm thick layer (remoulded loess is difficult to
compact). This heavy compaction of the loess material at a
water content drier than optimum produced a strong but brittle
fill that must have had a very low initial pore pressure.

A PI value of 3 for the loess core was subsequently determined
(i.e. post-collapse). This would indicate that, if the fill
was being placed at an undrained shear strength as low as 80
kN/m², a reduction in the placement water content of only 0.5%
could nearly double the strength (to 157 kN/m²) but an increase
of 0.5% would reduce the strength almost to zero (i.e. 3 kN/m²;
Penman 1987, p. 231). This sensitivity to small changes in
moisture content is a major reason why loess is not a suitable
material for large earth dam cores.

CONCLUDING DISCUSSION

Why was this unsuitable arid soil material used for the core of
this large dam? Where does the responsibility lie for the
major engineering failure? Sowers (1993) has discussed this
problem in an attempt to determine where shortcomings lay, but
in the current authors' opinion, he has not given sufficient
status to the peculiar nature of the soil fill for the core.
The implication of Sowers' discussion is that relatively minor
changes in design and construction procedures would have
prevented the problem. It is difficult to see how a successful
dam core could ever be achieved with loess, however laid or
treated, and it is apparent that more emphasis needs to be put
on the special nature of the loess prior to its use in
construction. Unusual arid soils do not fit easily into
current construction practices.

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An alternative approach to the understanding of the collapse mechanism in desert sands, loess and other collapsing soils

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ABSTRACT
Natural collapsing soils show the phenomenon of hydrocompaction or hydroconsolidation, and are often thought of as a special class of soil. However, their behaviour is analogous to the characteristics shown firstly by compacted soils placed dry of optimum and, secondly, by soils undergoing aging, or mild diagenesis. An alternative approach is thus to place collapsing soils into the context of engineering soils in general.

INTRODUCTION
Collapsing soils comprise a large group of diverse geological origins, which are characterised by a predominantly granular soil structure, a small proportion of fines and the phenomenon of collapse of the microstructure upon inundation, with or without a previous surcharge. The traditional understanding of these soils is that the fine matrix, perhaps allied to tension from moisture films, acts as a binding agent to the coarser granular skeleton. The collapse is traditionally envisioned as being the result of strength loss in the binding agent, allowing grain re-arrangement in the coarse fraction (Jennings and Knight 1957). The "collapse potential" for collapse upon inundation is determined for either a given value of normal stress using a single oedometer test (Jennings and Knight 1975, Luton and Saber 1988) or for any value of normal stress using the double oedometer test (Jennings and Knight 1957) as shown in Fig. 1.

NATURAL COLLAPSING SOILS
Three main categories are usually considered (Dudley 1970, Clemence and Finbarr 1981) as follows.

(i) Aeolian deposits including dunes, cover sands, loess, loessial soils and pyroclastic dusts.

(ii) Water laid deposits including alluvial fans, flood deposits and debris slide material.

(iii) Residual soils.

The first two of these categories (Quaternary age deposits) are the subject of this paper but the third is not (residual soils being examples of retro-grading soils where bonding is being destroyed by weathering). Soil in category (ii) raises a problem in that it could be expected that the water present at the time of deposition could have led to collapse but a mechanism whereby this could have been circumvented has been suggested by Roberts and Melickian 1970 (in Jones 1986).

MECHANISM OF COLLAPSE
The microstructures believed to be responsible for collapsible sands have been well illustrated by Barden et al 1973 and Clemence and Finbarr 1981, among others, and are shown in Fig. 2. S.P.M. photographs of collapsing sands can show textures similar to the simple idealisations as in Fig. 3 but can also take more complex forms (Fig.
WIND BLOWN SEDIMENTS
in the
QUATERNARY RECORD

5 - 8th JANUARY 1994

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STRUCTURAL ASPECTS OF LOESS GEOTECHNICAL PROPERTIES

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The characteristic morphometric and geometric features of the structure of loess soils are as follows: a) existence at the surface of sandy and coarse-dusty fractions of a multilayer and complex composition, the upper layer of this "jacket" being mainly of clay minerals and the inner one consisting of carbonates, amorphous silica and iron hydroxides; b) abundant aggregates of clayey and fine-dusty material, forming aggregates of globular type 0.01-0.25 mm in diameter; c) the presence of three types of pores: micropores 50-500 μm in size, inter-aggregate and inter granular pores 8-50 μm in size and intra-aggregate pores less than 8 μm; d) the existence of one-level, consisting (in the non-saturated state) of a highly porous structure of particle-grains, aggregate-grains, grainy-aggregate and aggregate types.

Among the qualities of loess structure bearing upon its energetics there are the following: a) prevalence of water non-resistant contacts of transition (point) type, embracing contacts formed by ionic-electrostatic forces between the clayey minerals, and contacts generated in salts and 3/2 oxides formation, where singular connections of chemical nature are developed; b) presence of phase (convention) contacts, arising from isolation of the volumetric phase of carbonates, other salts and 3/2 oxides, non-mobile or slowly mobile under water action; c) presence in the humidity associated with capillarity conditions, but disappearing as water saturation conditions are approached (close to 0.9-1.05 index), provoking rapid decrease in structural cohesion.

On the basis of the mechanism of loess subsidence there are two interconnected phenomena, developing during increase in soil moisture and resulting in the collapse of structural stability, soil consolidation and subsidence: a) decrease of interaction energy between structural elements and contacts due to transformation of transitional contacts into coagulational ones and b) structural transformation, consisting of transformation of loess structure from completed form into non-completed, as a result of destruction of water non-resistant clay and clayey-silty aggregates.

THE LOESS SEDIMENT TYPES OF SLOVAKIA, THEIR FABRIC AND PROPERTIES

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Based on studies of the Slovak Carpathian loess soils it appears that the loess mass is composed of various primary rock fragments and minerals, products of their secondary changes and different organic substances. These components are found in loess soils under various conditions. They are diversely distributed vertically depending on the terrain relief, the climate, the degree of dissection, the water table level and other factors. The fabric of loess reflects not only the sediment genesis, but affects also its engineering geological properties. Four basic groups characterise the loess sediments. They are: typical loess, sandy loess, clayey loess and loess-like sediments. They differ from each other in their fabric, microstructure, genesis, physical and mechanical properties, tendency to collapse and other properties. Collapse is one of the most significant properties of loess deposits and consists of sudden volume change under the influence of humidity, stress or loading. To explain the mechanism of loess collapse or “sagging” the process has been reproduced in a triaxial cell and the associated microstructural changes monitored.
Various approaches to the widespread problem of the hydroconsolidation and subsidence of loess have been suggested. These include considerations of rheology, thermodynamics, phase movements, particle packing, interparticle bonding, pore structure and distribution, catastrophe theory, topology, and simple structural frameworks. Chinese, North American and most European investigators tend to concentrate on mechanisms of loess collapse. The Russian literature, however, contains an extra dimension. Two approaches, the 'syngenic' and the 'epigenetic' approach, to the formation of subsiding loess have been defined in the literature. Most investigators follow a syngenic approach which appears to be a consequence of the aeolian idea of loess deposition. Some Russian writers, in contrast, promote an epigenetic approach in which collapsibility can develop in an originally non-collapsible material, which can then suffer from hydroconsolidation and subsidence. The basis of the phenomenon is a change in the packing structure of the major loess particles, and this can be modelled using simple Monte Carlo methods to develop appropriate structures. This paper aims to review the work done on this important subject. Serious investigation of hydroconsolidation and subsidence of loess began in the early nineteen-forties (fifty years ago) and this has been reported in a piecemeal manner. A detailed critical review of this diverse work is now overdue and this is presented here in the light of recent work in the United Kingdom. An attempt is made to describe the process in a phenomenological and a structural sense. The role of N. Ya Denisov in this development, as 'subsidence pioneer' is considered.

THE ORIGIN, TRANSPORT AND PRIMARY DEPOSITION OF LOESSIC MATERIAL

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There are three fundamental requirements for the formation of primary aeolian loess deposits: (1) a source of dust; (2) adequate wind energy to entrain and transport the dust; (3) the existence of a suitable deposition site where dust can accumulate in a relatively unmodified form. Additionally, long-term preservation of loess in the geological record requires favourable tectonic and palaeogeographic conditions which favour burial rather than erosion of the deposits following their formation. Contrary to some published views, there is no shortage of loess-size sediment either in modern surface environments or the sedimentary record, in which mudrocks composed of clay, silt and fine sand comprise approximately two-thirds. Many different types of unweathered surface, including weathered bedrock, unconsolidated sediments and soils, can provide significant sources of dust, and very large quantities of material are today deflected from arid and semi-arid parts of the earth's land surface. However, evidence from ocean cores and terrestrial loess sequences clearly indicates that rates of dust accumulation have varied substantially during the Quaternary, and in many areas were significantly higher than present during periods of cooler global climate. Conventionally this has been widely attributed to the following factors: (a) the greater extent of glaciation and frost weathering during Pleistocene cold stages, which both formed more primary silt-size material and allowed extensive reworking of pre-existing weathering debris by ice and fluvioglacial action; (b) the greater extent of aridity in many tropical and sub-tropical desert areas during cold stages of the Pleistocene, and (c) the greater intensity of global wind systems during cold stages due to steeper thermal gradients. In many temperate mid-latitude localities a clear temporal relationship has been demonstrated between glaciation/fluvioglacial activity and neighbouring loess formation. However, in the context of loess formation on the margins of deserts the relationships between aridity, wind intensity and rates of loess accumulation are much less certain. Although global climate modellers have often assumed a simple positive relationship between aridity and dust flux, and between average wind strength and dust mean grain size, detailed consideration of the sedimentological and other evidence indicates that a much more complex situation exists. In some circumstances, decreases in aridity have resulted in increased dust flux, due either to increased surface instability and dust availability or to increased incidence of dust transporting winds. The consequences of such changes for loess accumulation rates depend strongly on the nature of the environmental gradients in areas adjoining the dust source regions, and on the nature of the prevailing wind systems responsible for dust dispersion. Sharp environmental gradients, (reflected) by rapid changes in vegetation density and near-surface status, favour trapping of airborne dust relatively close to the dust source and consequently lead to relatively high rates of loess accumulation. More gradual environmental gradients, on the other hand, favour dispersion of dust over a wide area, leading to a much higher likelihood of surface erosion and reworking, and consequently much lower rates of net dust accumulation per unit area. Proximal dust deposition is also favoured by a dominance of near-surface wind systems, for example those associated with low-level inversions, which inhibit vertical mixing and high level dispersion of dust. Conversely, distal transport and deposition of dust is favoured by meteorological conditions which involve strong vertical mixing and incorporation into upper level wind systems. These points are illustrated by evidence from Israel, the Great Plains area of North America and northern China.

SEDIMENTOLOGICAL CHARACTERISTICS FROM SOIL PARENT MATERIALS OF AEOEAN ORIGIN: SOUTHEASTERN BUENOS AIRES PROVINCE, ARGENTINA

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This study concerns the grain size and mineralogical composition of the parent material of soils in the intermontane area of the Tandilia Range, a tectonic mountain system located in the southeastern sector of Buenos Aires Province, where altitudes reach 270m agl. Cenozoic sediments cover the intermontane areas and sometimes the horizontal summits of the ranges. The intermontane area is characterized by a landscape of hills up to 60m high with a complex morphology. The upper part of the stratigraphic sequence is composed of very fine sandy silts of aeolian origin (loess). The present soil has developed on these sediments which correspond to the last glacial and postglacial stages (Late Pleistocene to Holocene).

Particle size distribution is usually unimodal, with the mean grain size between coarse silt and very fine sand (3-5 phi units), mainly poorly sorted, positive to symmetrically skewed. The sediments can be classified as sandy loess according to sand fraction content.
Conditions favorable for generation of dust storms in the deserts of Middle Asia are produced during summer and fall, when lack of precipitation in combination with overdrying of soil surface, featuring only extremely sparse vegetation cover, open way to deflation processes even at otherwise modest wind speeds.

Dust haze, brought into the air by such storms, hangs there even after the storm episode is over and is transported by air streams in the lower troposphere to large distances, hence. Large particles quickly sediment to ground, testifying, as it were, to deflation processes, while the fine fraction remains suspended in the air for quite a while, forming haze.

The comparative analyses of granulometric composition of loesses and dust sedimented after a dust storm, as well as that of suspended aerosol indicate that mass distributions of all these fractions are identical to each other.

Estimated rate of loess accumulation

The actual data on periodicity of dust haze events and the natural model of their development both served as a basis for calculations of the rate of accumulation of loess in Tadzhikistan. A special technique was developed for that purpose.

The analysis of data thus obtained indicates that the power of accumulated loess deposits depends on the absolute height of site, on the local climatic features at station site, and on its distance from the dust source. The depth of precipitated aerosol layer sedimented annually varies from 0.04 mm/yr to 0.683 mm/yr. The average rate of loess accumulation over the territory of the Republic constitutes 0.2 mm/yr. Approximately the same rates were obtained for the early holocene when calculating the depth of soil horizons, corresponding to that temporal cross-section (Lomov, 1991).

Computational data were used to map the distribution of loess layer increments over Tadzhikistan. Mapped information mainly reflects the dependence of aerosol density on the local
absolute height. The maximum increment of loess is found in the valleys featuring the lowest absolute heights above the sea level.

Basing on that map data one may assume that the maximum depth of loess sediments should be found in the southernmost areas of Tadzhikistan. Actually, however, the available map of loess sediments for Tadzhikistan (Mirzobayev, et al., 1968) indicates, first, that the loess cover in the Southern Tadzhikistan is far from solid, and, second, that according to the latest data available the maximum depth of such sediments is found in the northern part of the areal of loess accumulation. Finally, patches are found of a paleoareal of loess accumulation, presently raised by tectonic process beyond 2500 m above the sea level.

Conclusions

Two principal conclusions follow from comparing the two maps:

1. Paleogeography of the Southern Tadzhikistan had been somewhat different during the Pleistocene, working to displace the paleogeographic niches of loess accumulation to central areas of the Republic; 2. active tectonic processes during the Pleistocene worked to form central mountain ranges in the Southern Tadzhikistan, breaking the homogeneous loess cover and initiating the processes of loess erosion from mountain slopes and down the river valleys. Reminders of loess layers (the so-called "Ourta Boz") found in the valleys of the Vakhsh, Pyandzh and other rivers testify to that. Such remnants usually tower for several tens of meters above the younger alluvial terraces.

Another original example of the same developments is that of the burial of loess sediments below the young sedimentary rocks in the Bishkent valley. That fact also points to deficiencies of the available technique used to map loess depths in Tadzhikistan.

The data obtained on the rate of loess accumulation during the Holocene explain certain isolation found between the different epochs in life and development of paleopeoples, at the same time pointing to certain continuity between them. For example, this refers to neolithic camps from the early Holocene substituted by those of the people of the Bronze Age in the Middle Holocene levels, and the horizons of the late Holocene soils with traces of medieval habitats, superimposed on them.