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New Data on the Maximal Thickness of Subsidence Strata in Loess Massifs

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Subsidence of loess masses as the capacity for deformation under loading when soaked (moistened) in response to natural or technogenic factors is their characteristic engineering–geological feature. According to modern notions, this feature is developed in polygenetic soils directly in the course of accumulation and early subaerial diagenesis of silty sediments in arid conditions (syngenetic subsidence), progressive lithogenesis of young soils in subaerial conditions, or supergene (including cryoeluvial) decompaction of diachronous and polygenetic soils (epigenetic subsidence) [1, 2]. Soils with relative subsidence equal to or exceeding 0.01 are assigned to subsidence ones.

The thickness of the subsidence strata (zone) is the most important characteristic of loess massifs. By the early 1980s, it had already been established that the maximal thickness of the subsidence zone of loess soils in North Eurasia was 35–40 m. According to prognostic estimates, it could reach 50 m [3] in the Tashkent region and 45 m [4] in the Yavan Valley.

Subsequent studies showed the real development pattern of such zones. Study of key engineering–geological loess sections in the USSR revealed that the thickness of subsidence loess soils at natural loading reached 44 m in the Otkaznoe section (eastern Stavropol region) and 43 m in the Adyrnyi section (eastern area of Dushanbe) [2, 5]. According to Galai [5, 6], the thickness is as much as 55 m in the Georgievsk area (Stavropol region).

Further studies revealed that subsidence soils are encountered at still greater depths in loess massifs of Central Asia. They were established down to a depth of 65.5 m in the Orlovka reference engineering–geological section. This section is located on the left bank of the Chu River in northern Kyrgyzstan.[1] The loess massif occurs there on Paleozoic metamorphic soils and coarse-clastic molasse of the Kyrgyz Formation. In the foothills of the Kyrgyz Ridge, loess masses conjugate with the Upper Pleistocene alluvial and proluvial deposits represented by pebble, gravel, and grus [7].

This area incorporates two levels of terraces of different ages (Late Pleistocene and Middle Pleistocene) located above the Chu River bed at 50–60 and 150 m, respectively. According to some researchers [8–10], the loess massif located at a higher level is composed of Middle Pleistocene deluvial–proluvial deposits, whereas the loess massif located at a lower level consists of Upper Pleistocene alluvial–proluvial deposits. According to Dodonov et al., the loess represents an eolian section and its upper 30-m-thick sequence correlates with "the uppermost Late Pleistocene soil and loess horizons in the loess–soil scale of the southern Tajikistan and Tashkent region" ([7], p. 143).

Workings characterizing this key section are located on the middle Pleistocene (?) higher terrace level and expose a 71.3-m-thick loess sequence on fluvial pebbles. The section includes four cyclites including loess soils, recent sediments, and three buried soils (figure).

The first and second loess cyclites are similar. These are composed of grayish and pale yellow, loose, porous, aggregated loam with sandy loam interlayers, which include intergrowths of tabular gypsum crystals and fragments of calcite grains, with a uniform impregnation of fine-dispersed carbonates. The thickness of cyclites I and II is 16.0 and 17.8 m, respectively.

The buried soil, first from the surface, is attributed to the light-colored gray soil subtype. The grayish brown, compact, slightly aggregated soil is made up of isomet-

[1] This section was studied by researchers from different institutions of Moscow (A.D. Dodonov, O.N. Romashina, A.P. Spivak, Ya.E. Shaevich, and others) and Beshkek (I.N. Konkina, V.V. Sgibnev, Sh.E. Usupaev, S.N. Tsybin, and others).

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ric segregations 0.15–0.25 mm in size, some of which were subjected to humification to a greater extent than the surrounding mass. Cavities are represented by isometric pores (0.1 mm) and round pores (0.3 mm). The slightly humificated groundmass comprises brown dispersed humus and abundant impregnation of carbonates. The lower part of the soil contains numerous microgranular calcite concretions.

In the second buried soil, the soil is aggregated (aggregates are as large as 1–2 mm) and carbonates are partially washed off their upper part. The groundmass is impregnated with carbonates. Efflorescence is developed around pores and carbonate growths. This soil can be attributed to the dark gray soil subtype.

The pale yellow and gray, slightly aggregated loess soils in the third horizon comprise microgranular calcite and primary calcite grains of a coarse silt dimension. In general, the soils are similar to overlying soils and are represented mainly by loam (more clayey in the lower part). The thickness is 9.1 m.

The composition and properties of the third buried soil and loess soils of the fourth cyclite are similar to those of soils in the overlying cyclite. Soils are more aggregated and composed of microgranular calcite. The loess horizon is represented by light loam. The thickness of the horizon is 18.9 m.

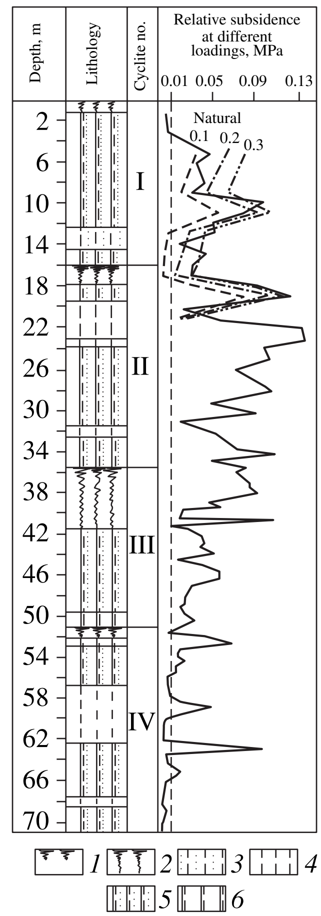
Soils are not salinized in most of the section. The average content of easily soluble salts (0.2%) increases to 0.4–0.8% in subsoil horizons. In the fourth cyclite, the content of salts increases drastically from 0.1% in the upper part to 5% at the base. Soils of the first buried soil belong to the highly salinized type (1.7%), whereas soils of the second and third buried soils belong to the unsalinized type (0.1%). Calcium–magnesium sulfate salinization is characteristic of the first cyclite, whereas magnesium–sodium chloride–sulfate is typical of the lower cyclites. All loess soils are characterized by alkaline conditions (pH = 8.4–9.0).

The gypsum content in loess soils makes up 0.1–4.2%. The carbonate content varies in the section from 6 to 22%, averaging 14%. The maximal content of carbonates was established in the lower parts of buried soils and subsoil horizons.

The humus content in loess soils and buried soils varies from 0.11 to 0.62%, making up 0.3–0.4% on average. The loss on ignition varies in the section from 0.01 to 0.03%, and its maximum value (up to 0.04%) is established in loess soils of the second cyclite.

The natural soil moisture varies in a stepwise manner from 8 to 16%, increasing in buried soils and horizons with the most dispersed composition. Maximal moisture was recorded in soils of the first cyclite and in the higher buried soil (up to 14–16%); minimal values, in the fourth cyclite (3%).

The soils of the section are characterized by high values of density of the natural structure (1.58–1.87 g/cm^3). Minimal density is typical of soils of the first cyclite, whereas maximal density is recorded in the third buried soil and loess soils of the fourth cyclite. The average density is 1.66 g/cm^3 in cyclites I and II and 1.77 g/cm^3 in cyclites III and IV. The character of dry bulk density variation in the soil section is similar to that described above: 1.44 g/cm^3 in cyclites I and II, 1.61 g/cm^3 in cyclites III and IV. The specific gravity of soil particles is stable for all soils, making up 2.70–2.72 g/cm^3.



The structure of the loess soil sequence and variation of relative subsidence in the Orlovka key engineering–geological section (based on Borehole C-2E core data). (*1*) Modern soil; (*2*) buried soil; (*3*) light silty loam; (*4*) heavy silty loam; (*5*) light loam; (*6*) medium loam.

The porosity of soils gradually decreases with depth from 47–50% in the upper horizons to 38–43% at the section base.

All soils of this key section represent the subsidence type at natural loading, except soils of the upper part (up to 3–4 m), the third buried soil, and the base of the fourth cyclite. Based on a value of relative subsidence equal to 0.01, the thickness of the subsidence sequence makes up 65.5 m (see figure). At this depth, the natural loading used for determination of the subsidence makes up 1.23 MPa.

It should be emphasized that the relative subsidence of loess soils is not equal to zero in deeper parts of the section as well. It makes up 0.008 at a depth of 66.2 m and 0.004–0.005 at the depth interval 67.6–69.6 m. The total value of subsidence in the loess soil massif is estimated at nearly 302 cm.

In conclusion, it should be pointed out that the value 65.5 m is the maximal thickness of the subsidence zone established at the current stage of investigations of loess soils (the relative subsidence adopted at present is ≥0.001). The greater value (87 m) presented in [11] was obtained for monoliths of loess soils sampled from the wall of a stripping of the Lyal'mikar section (the left bank of Surkhan Darya River, Uzbekistan). Under these conditions, the natural moisture of soils is lower compared to the regional background value, the soils are subjected to supergene decompaction, and subsidence soils are encountered at a greater depth compared to the unaltered part of the massif.

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