

VARIATIONS IN THE LATERAL MORPHOLOGICAL DIFFERENTIATION OF GILGAI SOIL COMPLEXES

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The structure of gilgai soil complexes is a combination of 3-D units complementing, entering and/or crossing each other and having different morphological features: colour, slickensides, dispersed calcium carbonate, calcareous and gypsum pedofeatures, eluvial (leaching) and solonetzic features. The 3-D units with these morphological features are described. Nine variations in the vertical-lateral morphological structure of gilgai soil complexes are identified on the basis of reviewing literature on Vertisols of tropics and subtropics. Thirteen variations of gilgai soil complexes are identified on the basis of observations on Vertisols within the East European Plain.

Key words: bowl-shaped structures, diapiric structures, slickensides, calcium carbonate, eluvial features.

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INTRODUCTION

The development of Vertisols with gilgai micro-relief is accompanied by both vertical and horizontal (lateral) differentiation of soil profile ([Hallsworth et al., 1955](#); [Paton, 1974](#); [Dudal and Eswaran, 1988](#); [Wilding et al., 1990](#); [Khitrov, 2003](#); [Khitrov et al., 2015](#)). As a result, gilgai soil complexes are formed. Nine variations in the vertical-lateral morphological structure of gilgai soil complexes are identified on the basis of reviewing literature on Vertisols of tropics and subtropics ([Khitrov, 2016](#)). More variations of gilgai soil complexes are identified on the basis of recent observations on Vertisols within the East European Plain ([Khitrov et al., 2015](#)).

The aim of the present paper is to describe the diversity of variations in vertical-lateral differentiation of gilgai soil complexes in the south of the East European Plain.

Study objects are gilgai soil complexes developed within the Volga-Akhtuba Floodplain, limans (large shallow closed depressions) of the Cis-Caspian Lowland, terrace of the Manych River, broad drain-

age-divide ridges and structural terrace within the Ynkul Depression ([Khitrov, 2003](#); [Khitrov and Rogovneva, 2014](#); [Khitrov et al., 2015](#)).

METHODS

For each of the study objects the following methods were applied: soil surface micro-relief survey using a dumpy level, soil trench (cross-section) through the main elements of the micro-relief, soil coring by a hand auger with registration of main soil horizons.

The soil description along the trench was based on the standard guidelines ([Kornblyum et al., 1982](#); [Guidelines ..., 2006](#)), which included identifying morphons, marking their delineations by coloured nails and recording their relative coordinates at each point: length along the trench and depth from the surface. The latter was subsequently transferred to a relative height above the conventional zero level for the whole trench. For that purpose, the trench surface height was determined using a dumpy level with a 5 cm step and interpolation between the points measured. The relative height of a point on the trench wall was calculated as a difference between the trench surface height at the respective point and the depth of the point required.

RESULTS AND DISCUSSION

To analyse the variations in the vertical-lateral morphological differentiation of gilgai soil complexes, the 3-D units having different morphological features are individually described below. Their images have resulted from recorded parameters of horizontal plane (micro-relief), lateral plane (four walls of the trench with intermediate planes recorded in the course of digging) and vertical soil cores taken at different points within the study plot. *The 3-D units of different colour* (Fig. 1):

1.1. A dark-coloured humus horizon with bowl-shaped structures of increasing thickness under micro-lows in combination with tongued diapiric structures of the lower horizons' material rising at an angle under micro-highs;

1.2. A network of gutter-like dark-coloured humified structures, parabolic in cross-section, under micro-valleys in combination with diapiric structures of the lower horizons' material rising at an angle;

1.3. Local elongated dark-coloured humified structures, bell-like in cross-section, under a fragmented network of curved micro-lows in

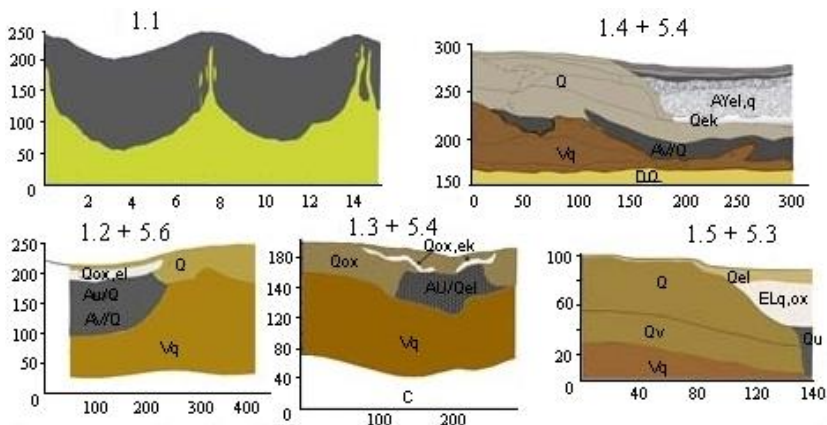


Fig. 1. The 3-D units of different colour. The numbers are explained in the text below.

combination with pillow-like weakly raised diapiric structures of the lower horizons' material;

1.4. Local surface U-shaped dark-coloured humified structures with eluvial (leaching) features within micro-lows in combination with deeper black concave lens-like structures under micro-lows with rising tongues at the lenses' edges under micro-slopes and weakly-raised diapiric structures of the lower horizons' material under micro-highs;

1.5. Local bowl-shaped bleached (eluvial, solodic) structures in micro-lows in combination with pillow-like diapiric structures of the lower horizons' material;

1.6. Layers non-differentiated by colour along the horizontal plane.

The 3-D units with slickensides (Fig. 2):

2.1. Weakly wavy layer of slightly varied thickness: the minimal thickness within the concave part in soils of micro-lows and the maximal thickness within the convex part in soils of micro-highs. The difference between the depths of the upper boundary of slickensides in micro-highs and micro-lows is $\Delta Z1 \leq 15-25$ cm. The difference between the depths of the upper boundary of the V horizon and/or the AV horizon in micro-highs and micro-lows is $\Delta Z2 \leq 15-25$ cm.

2.2. Weakly wavy layer of moderately varied thickness: $25 < \Delta Z1 \leq 40$ cm and $\Delta Z2 \leq 15-25$ cm.

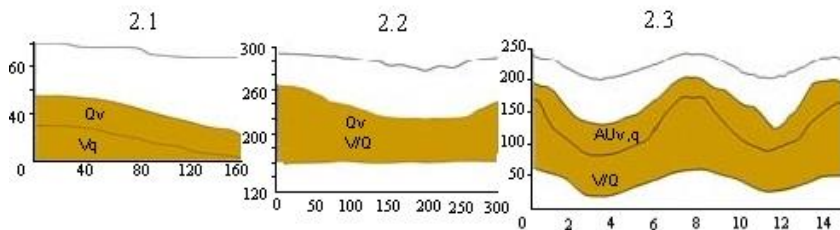


Fig. 2. The 3-D units with slickensides. The numbers are explained in the text below.

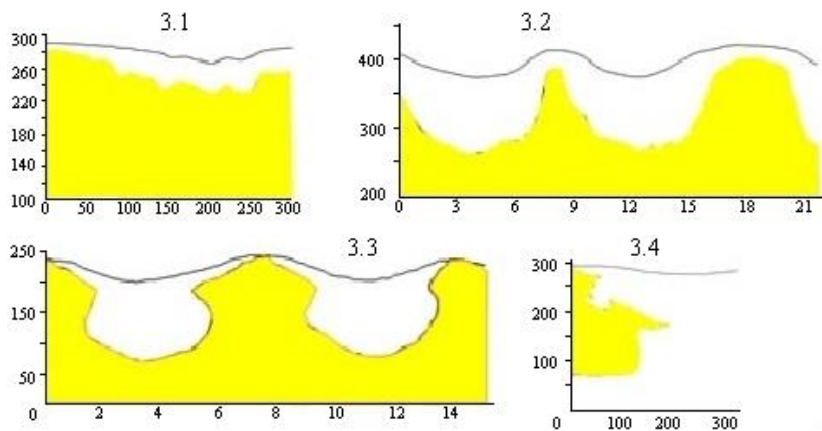


Fig. 3. The 3-D units containing dispersed calcium carbonate. The numbers are explained in the text below.

2.3. Wavy layer of strongly varied thickness: $\Delta Z1 > 40$ cm and $\Delta Z2 > 25$ cm.

The 3-D units containing dispersed calcium carbonate (effervescence with HCl) (Fig. 3):

3.1. A layer with weakly wavy upper boundary of total effervescence with HCl replicating the gilgai surface shape and having its relative height variation amplitude increased by no more than 1.5 times as compared to that of the gilgai surface as a result of weak leaching of calcium carbonate from soils of micro-lows.

3.2. A layer with strongly wavy boundary of total effervescence with HCl replicating the gilgai surface shape. Amplitude of vertical variation in its relative height is increased more than twice as compared to that of the surface, so that the upper boundary of effervescence coin-

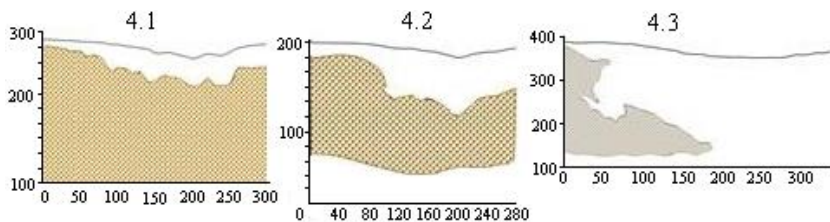


Fig. 4. The 3-d units containing calcareous pedofeatures. The numbers are explained in the text below.

cides with the lower boundary of dark-coloured horizons or occurs no more than 10-15 cm above the latter.

3.3. A layer with strongly wavy boundary of effervescence, having a wide concave minimum in soils of micro-lows and a wide convex maximum centred in soils of micro-highs and spreading to micro-slopes with formation of sagging edge resembling a mushroom cap.

3.4. A 3-D network of soil mass containing dispersed calcium carbonate under convex elements of micro-relief. Soils of micro-highs form thickened nodes of the net. Sides are often strongly deformed because of intrusion of carbonate-free soil tongues rising at an angle. The spaces between nodes are occupied by completely leached soils of micro-lows.

3.5. Absence of disperse calcium carbonate in all soils of gilgai complex.

The 3-d units containing calcareous pedofeatures (Fig. 4).

4.1. A layer with calcareous pedofeatures and weakly but consistently changing thickness: minimal within micro-lows and maximal within micro-highs. Calcareous pedofeatures are represented by hard and soft rounded segregations (“white eyes”) in all soils of gilgai complex.

4.2. A layer containing calcareous pedofeatures, extending to all soils of gilgai complex and having strong variation in thickness associated with the upper boundary variation: the minimal thickness coincides with a minimal content of hard calcareous segregations within the lower horizons of soils of micro-lows and the maximal thickness, as the layer approaches the soil surface, coincides with the maximal number of hard and soft concretions within micro-highs and the upper parts of micro-slopes.

4.3. The 3-D network with thickened nodes of soil mass containing calcareous pedofeatures under micro-highs, the upper parts of

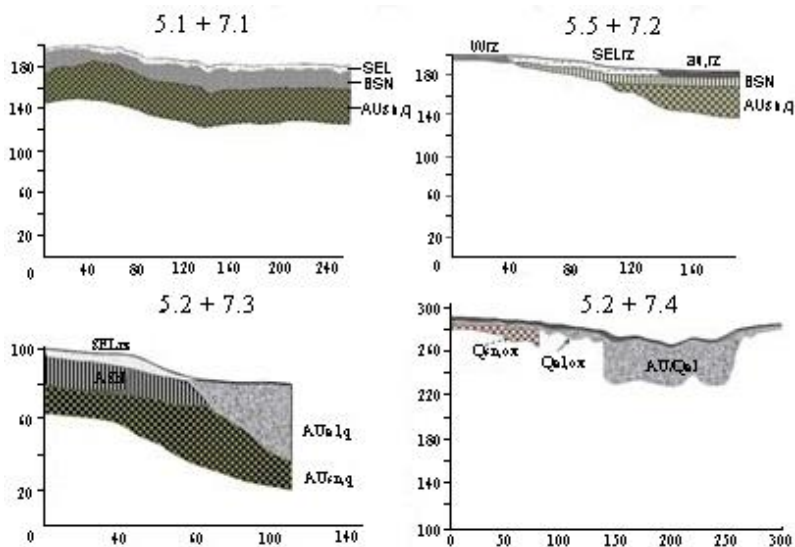


Fig. 5. The 3-D units with of eluvial (leaching) and solonchic features. The numbers are explained in the text below.

micro-slopes and saddles. In the nodes located within soil of micro-highs, the upper boundary is raised nearly up to the soil surface.

4.4. Absence of calcareous pedofeatures in soils of gilgai complex.

The 3-D units with features of eluviation (Figs. 1 and 5):

5.1. A layer represented by the SEL horizon.

5.2. A layer of varied thickness, with features of eluviation (el) in different diagnostic horizons of the gilgai soil complex: minimal thickness (<10 cm) in the Qox,el or SEL horizons in soils of micro-highs and micro-slopes, combined with a sharp downward increase in thickness in form of the AUel,q or AU/Qox,el horizons in soils of micro-lows.

5.3. Closed local bowl-shaped structures of the EL horizon in soils of micro-lows (Fig. 1).

5.4. Closed local bowl-shaped structures of either the AYel,q and Qek horizons, or the AU/Qox,el horizon, or the AU/Qel horizon in soils of micro-lows in combination with the Qek,ox horizon in soil of micro-slope (Fig. 1).

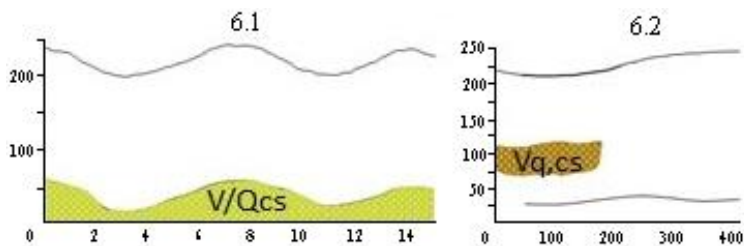


Fig. 6. The 3-D units with gypsum pedofeatures. The numbers are explained in the text below.

5.5. Local ring structures in form of a closed thin band of the SEL horizons in soils of micro-slopes (Fig. 5).

5.6. A dendritic network of thin (<20 cm) bands in soils of micro-valleys (Fig. 1).

5.7. Absence of eluviation features in all soils of gilgai complex.

The 3-D units with gypsum pedofeatures (Fig. 6).

6.1. A weakly wavy layer in the lower horizons of soils of gilgai complex.

6.2. A dendritic network of bands of lower horizons containing veins of fine-grained gypsum in soils of micro-valleys.

6.3. Absence of gypsum pedofeatures in soils of gilgai complex.

The 3-D units with solonetzic features (Fig. 5):

7.1. A wide-extent solonetzic layer being present in all soils of gilgai complex.

7.2. A local solonetzic horizon (lens) occurring within soils of micro-lows and micro-slopes.

7.3. A solonetzic lens within soils of micro-highs.

7.4. A local lens with solonetzic features.

7.5. Absence of solonetzic features in soils of gilgai complex.

Theoretically, there are over seven thousand combinations of the above-described 3-D units, but many of them are unreal. Various 3-D units with different morphological features are developing in a close relationship with each other under the influence of the five groups of processes. The first group of processes – significant changes in soil volume: Vertisols swell when moistened and shrink when dried, which leads to the formation of wide and deep cracks dividing the soil into vertical blocks of various sizes. The second group of processes – internal lateral-rising migrations of soil material from the lower horizons induced by shear and plastic deformations of the clay material. The

third group of processes – lateral re-distribution of water and solid particles along the curved soil surface that leads to spatial and temporal differentiation of soil moisture over micro-relief, local erosion of micro-highs and accumulation of run-off products within micro-lows. The fourth group of processes – the organic matter accumulation and transformation, calcium carbonate dissolution, migration and accumulation, iron and manganese reduction and oxidation resulting in red-ox pedofeatures, migration of soluble salts, solonetzization and solodization of different intensities depending on moisture differentiation over micro-relief. The fifth group of processes – gravitational fall of surface horizons' fragments into open cracks.

In total, there are 13 variations in gilgai soil complexes identified within the East European Plain. Their structure can be represented by the following combinations of the 3-D units described (Table).

Variations in the morphological structure of gilgai soil complexes represented by combinations of the 3-D units with specific morphological features: colour; v – slickensides; ca – disperse calcium carbonate; nc – calcareous pedofeatures; cs – gypsum; el – eluvial features; sn – solonetzic features. The 3-D unit numbers are given in the text above. Soil taxonomic designations correspond to the WRB-2014 codes (IUSS, 2014) in a micro-low → micro-high sequence.

No.	Trench no.	Soils	3-D unit codes and morphological features						
			colour	v	ca	nc	cs	el	sn
1	V-868	VR-pe-hu.st → VR-pe-st-qc	1.1	2.3	3.2	4.2	5.7	6.3	7.5
2	V-881	VR-qs.pe-hu.st-gyd → VR-so.pe-hu.st-gyd-qc	1.1	2.3	3.3	4.2	5.7	6.1	7.5
3	V-952	VR-pe-hu.st → VR-ha-st-qc	1.2	2.3	3.5	4.2	5.6	6.2	7.5
4	V-961	VR-ha-hu.st → VR-ha-ab.st-gyd → VR-cr-st-gyd-qc	1.3	2.3	3.3	4.2	5.4	6.2	7.4
5	V-579	VR-gyn-st.qs	1.6	2.1	3.5	4.4	5.7	6.1	7.5
6	V-587	VR-gyn.pe-hu.st.qs	1.6	2.1	3.5	4.1	5.7	6.1	7.5
7	V-224	SN-st.vr-ce.ct.hu → VR-so-st-qc	1.2	2.1	3.1	4.3	5.5	6.3	7.2
8	V-922	ST-ab.vr-slp.cen → VR-ha-st-qc	1.4	2.3	3.4	4.3	5.4	6.3	7.5
9	V-920	SN-st.vr.nm-ce.ct.hu	1.6	2.1	3.1	4.1	5.7	6.3	7.1
10	V-935	SN-st.qz.vr-ab.ce.cu.ct.hu	1.6	2.1	3.1	4.3	5.1	6.3	7.1
11	V-933	ST-ab.vr-ce.qc.qs → ST-vr.lv-ce.qc.qs	1.1	2.1	3.1	4.1	5.2	6.3	7.4
12	V-931	ST-ab.vr-slp.cen → ST-vr.lv-ce.qs	1.5	2.2	3.4	4.4	5.3	6.3	7.4
13	V-921	PH-st.vr-slp.cen → SN-st.vr-ce	1.1	2.1	3.2	4.3	5.2	6.3	7.3

CONCLUSIONS

1. The structure of gilgai soil complexes can be represented by a combination of 3-D units that compliment, enter and/or cross each other and have different morphological features.

2. The 3-D units have been systematized as follows: colour differences (6 units), slickensides (3 units), dispersed calcium carbonate (5 units), calcareous pedofeatures (4 units), gypsum pedofeatures (3 units), eluvial (7 units) and solonetzic (5 units) features.

3. Thirteen variations in the vertical-lateral distribution of morphological features within gilgai soil complexes have been identified within the East European Plain, with three of these variations being similar to those in tropical and sub-tropical Vertisols.

REFERENCES

1. R. Dudal and H. Eswaran, "Distribution, properties, and classification of Vertisols," In: *Vertisols: Their Distribution, Properties, Classification, and Management*, (Eds) L.P. Wilding and R. Puentes (Texas A&M University, College Station, TX, 1988).
2. *Guidelines for Soil Description* (FAO, Rome, 2006).
3. E. G. Hallsworth, G. K. Robertson and F. R. Gibbons, "Studies in pedogenesis in New South Wales. VII. The "Gilgai" soils", *J. Soil Sci.* 6 (1), 1–31 (1955).
4. IUSS Working Group WRB. 2015. [World reference base for soil resources 2014](#), update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Report 106. FAO. Rome.
5. N. B. Khitrov, "[Properties and regimes of vertisols with gilgai microtopography \(a review\)](#)," *Eurasian Soil Science*, 49 (3), 257–271 (2016).
6. N. B. Khitrov, *Genesis, Diagnostics, Properties, and Functioning of Clay Swelling Soils in the Central Cis-Caucasus* (Dokuchaev Soil Science Institutes, Moscow, 2003) [in Russian].
7. N. B. Khitrov and L. V. Rogovneva, "[Vertisols and vertic soils of the Middle and Lower Volga regions](#)," *Eurasian Soil Science*, 47 (12), 1167–1186 (2014).
8. N. Khitrov, L. Rogovneva, Y. Cheverdin, D. Rukhovich and V. Vlasenko, "Types and distribution of soil cover patterns with gilgai topography in Russia", In: *International Soil Science Congress on "Soil Science in International Year of Soils 2015"*, Sochi, Russia. Article book, 206–208 (2015).
9. N. B. Khitrov, V. P. Vlasenko, and L. V. Rogovneva, "[Statistic indices for bowl-and diapir-like morphostructures of vertisols in Vorontsovo depression padi](#)", *Byulleten Pochvennogo instituta im. V.V. Dokuchaeva*, 77, 3–28 (2015).

Byulleten Pochvennogo instituta im. V.V. Dokuchaeva. 2016. Vol. 86.

10.E. A. Kornblyum, I. S. Mikhailov, N. A. Nogina and V. O. Targulian, *Basic Charts for Morphological Description of Soils*. Field Manual. (Dokuchaev Soil Science Institute, Moscow, 1982) [in Russian].

11.I. R. Paton, “Origin and terminology for gilgai in Australia,” *Geoderma*, 11, 221–242 (1974).

12.L. P. Wilding, D. Williams, W. Miller, T. Cook and H. Eswaran, “Close interval spatial variability of Vertisols: a case study in Texas” In: *Proceedings of the Sixth Soil Correlation Meeting (ISCOM)*. Characterization, Classification and Utilization of Cold Aridisols and Vertisols. J.M. Kimble (ed.), USDA Soil Conservation Service, National Soil Survey Center, Lincoln, NE. 232–247 (1990).

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