Systematization of the topsoil fabrics in soils of the arid lands in northwest of central Asia

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Abstract
The micromorphological data concerning aridic soils are far from being numerous; therefore, the information presented contributes to the development of pedogenetic ideas and characterization of diagnostic horizons and genetic properties in the substantive-genetic classification systems. The diversity, functioning and resilience of aridic soils are basically determined by the properties of their topsoils, which are regarded as recent dynamic formations opposite to the subsoils mostly formed under different paleoclimatic environment; topsoil properties are more important for soil classification. Each of two upper horizons in the new Russian system of soil classification (the light-humus and xero-humus) has the same micromorphological features in different soils; however, in a sequence of soils, some individual micromorphological properties were revealed that indicate the increasing aridity. The micromorphological properties of the topsoils make it possible to identify the mechanisms of some phenomena: aeolian deposition, structural re-arrangement, dynamics of secondary carbonates, and cryptosolonetzic manifestations.

Key Words
Micromorphological analysis, genesis, classification of aridic soils.

Introduction
Micromorphology of aridic soils has been so far examined insufficiently because of problems with preparing thin sections of their friable and brittle topsoils. Nonetheless, most common soils of the USSR deserts and semideserts were described (Minashina 1966; Romashkevich and Gerasimova 1977; Gubin 1984; Gerasimova 2008). In other countries, the studies of desert soil pedofeatures started later (Figueira and Stoops 1983; Mills *et al.* 2008; Williams *et al.* 2008). As for classification purposes, the micromorphological properties of aridic soils have been thoroughly characterized by Allen (1985) in a special issue of Proceedings of American Soil Science Society. The objective of our research is to categorize the topsoil fabrics inherent to aridic soils in Russia and adjacent countries in compliance with the diagnostic elements of substantive classification systems.

Materials and methods
1. Soils. Objects of research are diagnostic horizons and pedofeatures inherent to virgin arid soils derived from non-saline parent materials. Under consideration is a wide spectrum of arid soils developed under conditions of increasing aridity in Russia, Uzbekistan. Particular fabrics of Aridic Calcisols and Yermic Regosols as exemplified by soils of Mongolia were discussed earlier (Golovanov 2005).
2. Diagnostic horizons and diagnostic (genetic) properties have similar functions in the new Russian system and in the WRB system. In different versions of both systems their taxonomic significance slightly changed, whereas the definitions remained the same. *Diagnostic horizons* in the Russian system comprise: *light-humus, eluvial-solonetzic* and *xero-humus* horizons.
The *light-humus (AJ)* horizon occurs in brown aridic (Aridic Calcisols), part of Solonetzes and Gypsic Kastanozems in Russia; its central image was derived from the Siltic Calcisols of Central Asia. *Eluvial-solonetzic (SEL)* horizon is regarded as indicative of degrading Solonetzes.
In the former version of the Russian classification system (RCS) (2004), the *xero-humus*, or *crusty-subcrusty horizon* (AKL) was introduced. It was defined as a paragenetic association of thin subhorizons: porous crust and platy ‘subcrust’. In Russia, it was identified only in the brown semidesert soils (Gypsic Calcisols), where it was discontinuous, rather weakly expressed, or its thickness was insufficient to fit criteria for a diagnostic horizon. That’s why, its diagnostic significance was reduced in the version of RCS-2008, and it was qualified for a diagnostic property, or microprofile – [akl]. The crusty subhorizon is rather compact although porous, brownish light gray, effervescent, its depth does not exceed 2-4 cm. The subcrusty subhorizon is loose, light in color, and has a lenticular-platy structure; both subhorizons are salt-free.

Irrespectively of the taxonomic significance, the described formation has much in common with the *yermic horizon* in the WRB system. By definition, the yermic horizon has the same ingredients – the porous crust with stony inclusions of desert pavement underlain by a fragile platy layer (WRB-1998), while in WRB-2006 this sequence was indicated as being not obligatory. In both WRB definitions, aeolian phenomena and aridic properties are included in the definition.
In the Russian system, the elements of aridic environments and soils are recorded at the level of diagnostic properties, which is justified by the geographic reasons. The following diagnostic properties are specified: takyric (kt), pendent-carbonate (ic), gypsic (cs), saline (s); aeolian-accumulative (ael).
Sampling from soil pits was done at small intervals to characterize the subhorizons. Thin sections were prepared by M.A. Lebedev in the laboratory of Dokuchaev Soil Institute; synthetic resins were used for the impregnation procedure under vacuum, which provides the preservation of crystalline pedofeatures.

Results
Light-humus AJ horizon is characterized based on the data for Siltic Calcisols, Gypsic Kastanozems and Gypsic Calcisols soils, moderately Deep Mollic Solonetzes. The topsoil of a typical Siltic Calcisols (Uzbekistan, piedmont plain of the Turkestanskii Ridge) is light brown, weakly compact, with moderate crumb structure, many fine roots and faunal chambers. It has the following set of micromorphological properties: high pedality and porosity, carbonate-clay plasma; mostly rounded aggregates, 0.1-0.2 mm in diameter, the largest are faunal castings; 'loessic microaggregation' (according to Minashina 1966) with aggregates 0.02-0.05 mm in size, is recognized in some parts of thin sections. Plasma is weakly anisotropic, b-fabric is crystallitic. Packing voids with clear walls are predominant among pores. Fine organic residues including root remains in voids are few, as the fine-dispersed organic matter. These characteristics of serozems are typical for the upper horizons of soils on loess and they may be regarded as composing a 'central image', or micromorphotype (Gerasimova 2003) of the light-humus horizon. The transformation of parent rock (loess) fabric into that of the AJ horizon is due to soil fauna, effects of roots and microbial transformation of organic residues during the short period of spring rains.

The light-humus horizon of Gypsic Kastanozem (Gerasimova *et al.* 1996) has a dark color as compared to AJ horizon in other soils, the strongest crumb structure with a higher proportion of biogenic aggregates, the most abundant root residues; it may be even partially free of carbonates. The light-humus horizon was also studied in moderately deep Deep Mollic Solonetzes of Dzhanybek experimental station, northwest of the Caspian Lowland (Lebedeva and Gerasimova 2009). It was found out recently that properties of AJ horizon in this area are not stable because of changing microrelief and activity of burrowing mammals bringing calcareous and saline material to the surface. Therefore, they range from those in light-colored and highly calcareous variants to rather dark, structured and leached ones. In the moderately Deep Mollic Solonetzes, the AJ horizon merges into the eluvial-solonetzic (SEL) one followed by the solonetzic (natric) subsoil. The SEL horizon displays micromorphological evidences of clay and humus depletion in the uppermost parts of columnar peds.

In terms of micromorphology, the AJ horizon has the following properties: brown disperse humus, predominance of moderately decomposed plant residues, specific microstructures: rounded aggregates arranged in fine plates. Admixtures of apedal micrite-enriched material were also found; they testify to the translocation of subsoil substrate into the AJ horizon (Lebedeva and Gerasimova 2009). Episalic Solonetzes (Yermic) were also studied in microcatenas in Dzhanybek experimental station; they are confined to the driest microhighs almost without vegetation, and their surface is dissected by fissures into small polygons. They differ of other Solonetzes by shallow topsoil above the solonetzic horizon composed of crusty and subcrusty subhorizons, 2 to 4 cm thick each. The lower part of the porous crust is gradually acquiring a horizontal stratification and merges in the subcrusty subhorizon. Presumably, this stratification may be maintained by freezing/thawing cycles. No features of SEL horizon were identified. In thin sections, the crusty K subhorizon is homogeneous and compact, has silty-plasmic elementary fabric, isolated isometric pores, including the rounded ones, mostly vesicular. The subcrusty L subhorizon is of the same texture, but has elongated or horizontal voids, partially fine planes.Gypsic Calcisols and Yermic Calcisols have their AJ horizons basically corresponding to its central image (Gubin 1984), and with inclusions of morphons of the crusty-subcrusty microprofile (akl). The latter may be either complete – composed of both layers, or represented by one of its ingredients. Our observations in the Caspian Lowland have shown that the proportion between the AJ and akl morphons depends on texture: the lighter the texture, the lower is the share of akl morphons. In other words, the akl morphons are rather confined to loamy plots with sparse vegetation, while under the bunch grasses they are replaced by the AJ morphons. Micromorphology of Gypsic Calcisols in the southern Caspian Lowland was studied by one of the authors in the near-coastal hummocky area. The light-humus horizon has a c/f related distribution close to gefuric: sand-size grains are interconnected by clay braces or coatings; packing voids prevail, plasma is carbonate-clay with clear micrite concentrations, very few plant residues are weakly decomposed, and black tissue residues occur as well; faunal casts are very few. Vesicular pores were recorded only once in an AJ of heavier texture. Grain coatings are laminated: the inner layers are clay, while the outer ones are carbonate-impregnated. There were no evidences of platy microstructure, which may be explained by light texture.

The xero-humus AKL horizon (or akl property) is inherent to desert soils. In the sequence of soils with increasing aridity up to the Yermic Regosols of Mongolia, the akl property is gradually replaced by the AKL horizon, as the latter is described in (Lebedeva *et al.* 2009). Moreover, the depth of the xero-humus horizon increases and its differentiation into crusty and subcrusty subhorizons becomes more distinct. The Yermic Calcisols of Uzbekistan is affected by current aeolian accumulation of loessic weakly calcareous material with inclusions of rounded aggregates. The crusty subhorizon abounds in voids – vesicular and packing voids among weakly separated aggregates; the void system is basically open. The clay plasma is impregnated by carbonates, although there are few fine and discontinuous grain coatings. The skeleton grains are weakly sorted, sand- and silt-sized, few of them are weakly rounded, they produce a porphyric c/f ratio. The subcrusty subhorizon has a horizontal stratification – fine platy or scaly-platy microstructure with horizontal packing voids; in some soils, weak rounded aggregates included in the plates may be recognized; the impregnation by carbonates is low in some parts, no evidence of clay plasma mobility, few fresh castings of woodlouses.

Aeolian accumulation is an additional mechanism contributing to the formation of xero-humus horizon, or overlain upon it. Aeolian aggregates are easily identified in the in-blown silt by their shape, distinct boundaries, higher clay content and c/f ratio different of that of enclosing material. Such rounded aeolian aggregates participate in the fabric of the AKL horizon; they are more distinct in the subcrusty ingredient, where they form primary peds in platy microstructures. In the crusty ingredient, they coalesce; packing voids between them may be mitigated by the infillings. Thus, major elements of the AKL horizon being well expressed macro- and micromorphologically in the Yermic Calcisols of Uzbekistan are complemented by aeolian phenomena (*ael* property).

Table 1. Diagnostic elements of aridic topsoils identified at a micromorphological level.

Soil (WRB-2006)	Diagnostic horizons [1]				Genetic features[2]					
	AJ	*AKL*		*Desert pavemen*	*[akl]*	*ael*	*ic*	*dc*	*s*	*cs*
		K	L							
Siltic Calcisols	+[2]									
Gypsic Kastanozems	+									
Deep Mollic Solonetz	+									
Gypsic Calcisols	(+)	+		(+)	+	(+)				(+)
Episalic Solonetz (Yermic)		+	+		+	(+)				
Aridic Calcisols		+	+	(+)		+	+	(+)		(+)
Yermic Calcisols		+	+	+		+		(+)		(+)
Yermic Regosols		+	+	+		+		+	+	(+)

[1] Symbols for horizons: *AJ* – light-humus; *AKL* – xero-humus, *K* – crusty and *L* –subcrusty subhorizons.
[2] Genetic features: microprofile - *[akl]*; aeolian-accumulative – *ael;* dispersed-carbonate – *dc;* pendant-carbonate – *ic;* saline – *s;* gypsum-containing – *cs.*
[3] Conventions: + diagnostic horizon or genetic feature is present; (+) – horizon or feature is optionally manifested; empty column – horizon or feature has no manifestation.

Conclusion

In a soil sequence with increasing aridity, the diagnostic horizons and properties are combined in a regular way corresponding to the changes in soil formation conditions and soil-forming processes; in the same time, the sequence is in good agreement with diagnostic elements of substantive classification systems (Table 1). Thus, the soils studied form two groups: with a distinct light-humus AJ horizon, and with a xero-humus AKL horizon composed of K and L subhorizons; these groups correspond to two types of pedogenesis, respectively. The former is the dry-steppe humus-accumulative type (minimal variant), the latter – the desertic

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"crust formation" manifested in the structural re-arrangement of the solid phase. With this approach, Gypsic Calcisols soils may be regarded as intergrades between steppe and desert pedogenesis types; Episalic Solonetz (Yermic), despite their occurrence in the dry steppe, seem to be closer to the desert type unlike Deep Mollic Solonetz.

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