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SOIL PHYSICS

Physical Properties of Thalassosols in the Coastal Zone of the Sea of Japan

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Abstract—Particle-size distribution and physical properties of the soils of coastal lowlands in the Russian part of the coastal zone of the Sea of Japan are analyzed. These soils are referred to as a specific group of Thalassosols. Regional peculiarities of Thalassosols are considered in the context of global variability in the properties of coastal soils.

INTRODUCTION

The term "Thalassosols" in the title of this article has already been used in our previous works [14, 15]. However, it requires commenting. Thalassosols can be defined as azonal soils developing under herbaceous vegetation in relatively narrow strips of coastal lowlands adjacent to the sea and strongly affected by it. Thalassosols are characterized by specific morphology and properties. They form a classification group of high taxonomic level (an association of soil types).

Physical properties of Thalassosols are not so specific as their morphological features or chemical properties. However, the study of physical properties is necessary for a comprehensive characterization and analysis of Thalassosols.

Works that specially analyze physical properties of coastal soils are scarce in number. Usually, these properties are studied together with the other soil characteristics.

The texture of coastal soils may vary in a wide range: from loose sandy deposits to heavy clays. Often, Thalassosols develop from stratified rocks; the degree of contrast between separate layers may be very considerable.

Thus, marsh soils in the Elba River estuary contain up to 80% of clay; impermeable clayey horizons can be found in the profile of these soils [24]. All marsh soils in the Guadalquivir River valley (Spain) also have a heavy texture [26]. The predominance of clay and fine silt particles is typical of marsh soils in New Jersey [23]. The soils of marshes in northwestern Spain have a loamy texture; the content of sand particles in them varies from 16.6 to 58.2% [16]. Marsh soils in the mouth of the Apalachicola River (Florida) develop from contrasting deposits (sandy and clayey layers); the adjacent soils of swamps unaffected by tides are composed of silty–clayey material. The clay content in these soils may be as high as 92%, whereas sand particles are absent [17, 18].

To the contrary, the predominance of sandy soils is typical of some coastal areas in northern Ireland. Even peat soils develop on sandy substrates in this region. Loamy layers were only found in the soils developing near a river estuary [25]. Marsh soils in the northeast of Russia are also characterized by a coarse texture. The clay content in them does not exceed 10% (usually, 3–8%) [10]. In coastal soils of the Andhra Pradesh state (India), the sand content decreases down the profile (to a depth of 180 cm) from 92.5 to 80.0%, whereas the clay content increases in the same direction from 4.5 to 15.3%. The silt content in these soils is relatively low (2.3–5.6%) [20]. Egorov [5] distinguishes two types of marsh soils in the Caspian Lowland: sandy soils and clayey soils (clayey material is underlain by sands at some depth). Gennadiev *et al.* [4] have described sandy soils of marshes in the Turali site (Dagestan). Often, these soils are enriched in shell detritus and gravelly material. However, buried or surface horizons of marsh soils developing from bottom deposits of drained lagoons have a heavier texture and are enriched in clay particles. These data are in agreement with the data obtained by Egorov. The marsh soil of the Old Point (Maryland) is characterized by a very uneven distribution of sand and coarse silt particles along the profile; the physical sand content varies from 8.5 to 92.7% [30]. The texture of soils in the southeastern Atlantic coast of the United States is very diverse (from sandy to silty–clayey) [21]. Mangrove soils in the Umgeni River estuary (South Africa) are even more diverse with respect to their texture (from sandy to clayey) [27]. Saline coastal soils of Estonia have a loamy or sandy–loamy texture with considerable textural variations along the soil profiles [7, 11, 12]. Marsh soils in the White Sea coast (Karelia) can be subdivided into clayey, loamy, silty–sandy, and sandy. There are also organic soils underlain by pebbles and sand [13].

The particle-size composition of coastal sediments and the soils developing from them is dictated by the particular type of sedimentation. For instance, heavy-textured marsh soils in Maryland are found in the inland part of the lagoon coast, whereas sandy soils occupy the seaward coast [19].

The distribution of size fractions along the profiles of coastal soils is very uneven and rather random. However, a general tendency toward an increase in the content of fine particles in the upper soil layers can be observed. This regularity has been noted for coastal soils in the United States [17, 19], Spain [16], and Estonia [7, 11]. It can be explained by the continuing sedimentation of fine particles from tidal water. The herbaceous vegetation growing on the surface of marsh soils serves as a mechanical barrier for fine particles and favors their accumulation on the soil surface. Thus, we deal with a rather specific argillization of surface horizons.

This brief review of Russian and foreign literature on physical properties of marsh soils allows us to group them into three classes: (1) the soils with predominance of sand (sandy and loamy–sandy soils), (2) the soils with a high content of clay material (loamy and clayey soils), and (3) the soils enriched in organic material (organic soils). The soils of transitional character are also be distinguished.

As a rule, sandy layers of coastal soils are structureless and loose; sometimes, they are somewhat compacted (coherent sands) or even rather dense [6, 8, 9]. Sandy horizons are characterized by a high water and air permeability. Therefore, the aeration of sandy soils is rather good; they are not so strongly affected by waterlogging as clayey soils. The bulk density of sandy soils is somewhat higher than 1 g/cm^3. The water content does not exceed 10–20%. The bulk density decreases and the water content increases in loamy sands. For example, the water content in loamy–sandy horizons of marsh soils in the Apalachicola Estuary varies from 29 to 60% [17]. Loamy and clayey soils of coastal lowlands are also structureless. Soil structure develops in the soils outside the littoral zone; however, the structural status of these soils is rather poor [5, 8, 8, 17, 18, 30]. Loamy and clayey marsh soils are sticky; their water permeability and aeration porosity are very low [17, 18, 26, 29].

The bulk density of loamy and clayey marsh soils varies within a wide range. For example, the bulk density in different marsh soils of Maryland (Sulfaquents, Hydraquents, and Sulfohemists) varies from 0.19 to 0.94 g/cm^3 at the natural water content varying from 61 to 442% (by weight). This is explained by the considerable content of organic matter in these soils. In two soil layers, the bulk density is somewhat higher (1.040 and 1.328 g/cm^3) at the moisture content of 204 and 40%, respectively. Both layers are composed of mineral material underlying the organic horizon of Terric Sulfohemists [22]. The study of the top 10 cm in marsh soils of the Mississippi Delta showed that these horizons in saline soils of marshes are composed of mineral material with a considerable admixture of organic substances. Average bulk density values in saline marsh soils are about 0.24 g/cm^3; in slightly saline soils, they decrease to 0.16 g/cm^3. The greatest part of soil volume (88 and 91%, respectively) is occupied by pores filled with water and gases [28]. The water content in loamy and loamy–clayey (according to the Russian classification) marsh soils near the Apalachicola Estuary varies from 40 to 105%; in heavier soils, it increases to 78–456%. The water content in clayey horizons of swampy soils adjacent to marshes varies from 73 to 551% [17, 18].

Coastal peat soils are characterized by very low bulk density, high porosity and water-holding capacity, and low water permeability. The water content in organic horizons of marsh soils in Florida ranges from 359 to 738%; it is somewhat lower (246–593%) in the soils of coastal swamps outside the tidal zone [17, 18]. According to Griffin *et al.* [22], the bulk density of peaty soils of marshes in Maryland varies from 0.07 to 0.14%, and their porosity, from 92 to 96%. The organic matter content in these soils reaches 2.36–4.91 vol %; mineral material constitutes just 1.33–3.18 vol % [28].

Thus, the bulk density of coastal soils generally decreases from sandy to clayey soils and from mineral to organic soils. A simultaneous increase in the water-holding capacity is observed. Heavy-textured and organic soils are characterized by lower values of infiltration capacity and aeration porosity in comparison with those in coarse-textured mineral soils. A decrease in aeration porosity leads to a more intensive development of anaerobic processes.

To ease the understanding of the following presentation, let us consider the classification of Thalassosols suggested in our previous works [14, 15]. Soil differences within the group of Thalassosols are mainly caused by the degree of hydromorphism and the kind of parent material (mineral or organic). These indices serve as the basis for classifying Thalassosols (Table 1). Six types of Thalassosols can be distinguished. Littoral (synlithogenic, i.e., developing under joint action of pedogenic and lithogenic processes) Thalassosols are traditionally referred to as marsh soils. The Thalassosols lying outside the tidal zone and unaffected by tides (postlithogenic soils) are called maritime swampy and maritime meadow soils.

The subdivision of Thalassosols at lower taxonomic levels is based on the degree of manifestation of the main and auxiliary pedogenic processes, the degree of soil profile development, the content and composition of salts, and the lithological peculiarities of parent rocks. The latter criterion is used to differentiate between three varieties of mineral Thalassosols: (1) normal soils that develop from lithologically homogeneous substrate, (2) multilayered soils developing from stratified (often, contrasting) deposits, and (3) polycyclic soils that contain buried soil horizons (or even buried soil profiles). At the lowest level, organomineral and mineral Thalassosols are subdivided on the basis of particle-size composition in the upper (0–50 cm) layer.

Table 1. Classification of Thalassosols (scheme)

Parent material	Stage of hydromorphism		
	hydroaccumulative	hydromorphic	mesohydromorhic–automorphic
Mineral	Marsh soils	Maritime meadow-swampy soils	Maritime meadow soils
Organic	Organic (swampy) marsh soils	Maritime swampy soils	Maritime meadow-swampy (organic) soils

The goal of this paper is to analyze data on the particle-size composition and physical properties of the main types of Thalassosols studied by us on coastal plains in the southern part of the Russian Far East (from the northern border of North Korea to the town of Nakhodka).

MATERIALS AND METHODS

Undisturbed soil monoliths were sampled from 33 pits; the samples were collected from all genetic horizons in five to six replicates.

Soil bulk density and field water content were determined by routine methods [1, 3]. The samples placed into weighting bottles were dried up to the constant weight at 105°C. The solid phase density was determined by a pycnometer. The study of hydrophysical properties was performed by standard procedures via artificial saturation and drying of soil samples [1, 2]. The particle-size distribution analysis was conducted using a pipette method. Sodium pyrophosphate was used for the preliminary dispergation of soil samples [2].

RESULTS

The analysis of particle-size distribution data shows us that the particle-size composition of Thalassosols is inherited from parent rocks. The changes in soil texture induced by pedogenic processes are insignificant because of a short duration of pedogenesis and, often, high resistance of parent material (quartz sand) to weathering. Thus, the particle-size composition of Thalassosols is dictated by geological processes of sedimentation in the littoral zone and on tidal marshes. Open areas subjected to strong wave action are characterized by the predominance of coarse-textured deposits composing sea terraces and barrier bars. The soils of these geomorphic elements have a sandy or loamy–sandy texture. The shores of small lagoons and inlets protected from oceanic waves are composed of relatively fine-textured material. Loamy and clayey Thalassosols develop in these locations. As the position of coastlines is not stable, the conditions of sedimentation may change with time. Within several hundreds of years, a stratified multilayered sediment may form. This stratification is obvious in many profiles of Thalassosols (Table 2). An especially fine stratification is typical of Thalassosols in delta and estuary areas because of very unstable conditions of sedimentation in these zones.

A general regularity of spatial changes in soil texture is observed on coastal plains: Elevated geomorphic positions are occupied by relatively coarse-textured soils, whereas the soils of depressions contain maximum amounts of fine particles. However, even the soils of depressions (maritime swampy soils) are not necessarily connected with clayey and loamy substrates.

Known in the coastal soils of some other regions (see above), tendency toward an increase in the content of fine particles in topsoil layers can also be traced in Thalassosols of coastal plains of the Sea of Japan. This tendency is better manifested in the soils developing from homogenous parent rocks. It is often hidden in polycyclic and multilayered Thalassosols.

Vast territories are occupied by Thalassosols with the predominance of physical sand (>0.01 mm) over physical clay (<0.01 mm). The fractions of coarse silt and fine sand predominate in marsh and maritime swampy soils. The predominance of coarse and medium sand fractions is typical of maritime meadow soils. Maritime meadow-gley soils occupy the transitional position.

As expected, physical properties of Thalassosols are governed by the particle-size composition and the organic matter content of these soils. The whole diversity of layers and horizons found in Thalassosols can be classified into four groups (Table 3). The term *transitional horizons* in this table means that these horizons occupy an intermediate position between humus-accumulative (A) and mineral (C, G) horizons: AC, AG, etc. The size of statistical samples used for calculation of averaged values varied from 25 to 44 horizons. The data of Table 3 show us that the bulk density of soil horizons, as well as their solid phase density, increases and the field water content decreases from organic to mineral soils. At the same time, all these indices are characterized by considerable variability, so that the values characteristic of a given type of horizon may overlap with the values typical of a different type of horizon. For instance, some low-humus heavy-textured horizons may have a lower bulk density and a higher porosity than a peaty horizon with considerable admixture of clay. Such mineral horizons are typical of the soils of shores of small lagoons and closed inlets protected from the wave action, where the sedimentation

Table 2. Particle-size composition of Thalassosols, %

Horizon	Depth, cm	Size of particles, mm						Sum of particles	
		1–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	>0.01	<0.01
Typical marsh poorly developed multilayered loamy–clayey soil									
A_O	0–10	2.8	7.9	39.8	8.1	23.4	18.0	50.5	49.5
$G1A_O$	10–25	1.3	8.5	45.4	9.8	9.7	25.3	55.2	44.8
$G2A_O$	25–47	4.7	10.9	35.3	8.3	12.8	28.0	50.9	49.1
DG	47–70	61.4	14.7	12.9	2.3	2.9	5.8	89.0	11.0
Typical maritime deep multilayered meadow-swampy loamy soil									
A_O	0–15	10.0	11.4	31.5	12.6	20.8	13.7	52.9	47.1
A_Og	15–27	14.1	36.1	20.6	9.9	10.8	8.5	70.8	29.2
G	27–40	24.5	55.3	10.0	0.3	6.3	3.6	89.8	10.2
Maritime deep polycyclic meadow gley loamy–sandy soil									
Ap	0–30	0.9	41.2	39.3	2.5	6.2	9.9	81.4	18.6
Bg_{Fe}	30–44	0.6	33.4	48.3	4.9	6.4	6.4	82.3	17.7
T	44–52	Organic material							
B1G	52–85	0.5	38.9	44.0	1.8	6.9	7.9	83.4	16.6
B2G	85–120	0.5	44.5	37.8	2.1	8.2	6.9	82.8	17.2
CG	120–170	1.4	43.1	39.8	3.7	4.7	7.3	84.3	15.7
Typical maritime shallow polycyclic meadow sandy soil									
A1	0–10	79.2	9.0	6.3	1.0	3.0	1.5	94.5	5.5
C	10–25	78.0	8.3	6.2	0.1	5.6	1.8	92.5	7.5
[A]	25–60	4.3	30.6	32.6	8.2	16.9	7.4	67.5	32.5
ADg	60–80	40.5	29.0	14.0	4.5	7.9	4.1	83.5	16.5

Table 3. Physical properties of separate horizons of Thalassosols

Type of soil horizons	Bulk density/solid phase density			Natural water content, wt %/vol %		
	mean	variation range	root-mean-square deviation	mean	variation range	root-mean-square deviation
	g/cm^3					
Organic	0.42/2.09	0.15–0.66/1.51–2.44	0.15/0.23	184.7/62.5	45.9–490.4/27.6–76.2	111.2/11.3
Humus-accumulative	0.91/2.51	0.44–1.51/2.05–2.69	0.32/0.17	62.5/44.1	6.5–159.0/8.1–70.0	44.9/19.1
Transitional	1.04/2.61	0.65–1.46/2.50–2.69	0.30/0.08	40.1/40.7	4.6–67.0/6.8–60.3	24.0/18.9
Mineral	1.33/2.62	0.55–1.54/2.30–2.79	0.19/0.11	25.7/30.7	3.1–126.9/4.4–69.8	22.0/17.7

Table 4. Variations in physical properties of Thalassosols

Property	Groups of Thalassosols					
	typical marsh	alluvial marsh	swampy maritime	swampy-meadow maritime	meadow gley maritime	typical meadow maritime
Bulk density, g/cm^3	0.23–0.44 / 0.55–1.41	0.53–0.62 / 1.18–1.48	0.15–0.98 / 0.84–1.40	0.44–0.66 / 1.32–1.33	0.29–1.23 / 1.31–1.49	0.98–1.51 / 1.17–1.54
Solid phase density, g/cm^3	2.23–2.35 / 2.24–2.74	2.23 / 2.32–2.79	1.51–2.69 / 2.58–2.75	2.00–2.44 / 2.60–2.68	1.74–2.65 / 2.50–2.73	2.53–2.68 / 2.56–2.73
Natural (field) water content, wt %	159–277 / 29–127	109 / 29–46	57–490 / 27–66	46–150 / 30–32	34–227 / 9–31	7–41 / 3–29
Maximum water capacity, wt %	216 / 31–137	115 / 30–47	65–536 / 36–54	103–161 / 33–36	41–150 / 24–30	31–57 / 27–33
Field water capacity, wt %	191 / 28–125	107 / 26–44	56–440 / 32–49	61–151 / 29–30	33–136 / 17–22	16–45 / 10–25
Total porosity, vol %	81.3–83.0 / 45.8–76.1	72.2 / 44.2–56.1	63.6–91.5 / 47.2–59.3	71.0–80.3 / 49.2–50.4	51.5–83.3 / 43.8–50.8	44.5–61.7 / 42.3–57.1
Aeration porosity, vol %	10.5–11.3 / 3.2–6.7	4.9 / 2.2–7.8	8.2–21.7 / 4.9–9.9	6.4–48.4 / 7.6–9.9	8.9–28.5 / 9.6–35.6	10.7–46.8 / 5.6–46.5

Note: Data on organic and humus-accumulative horizons are given above the line; data on transitional and mineral horizons, below the line.

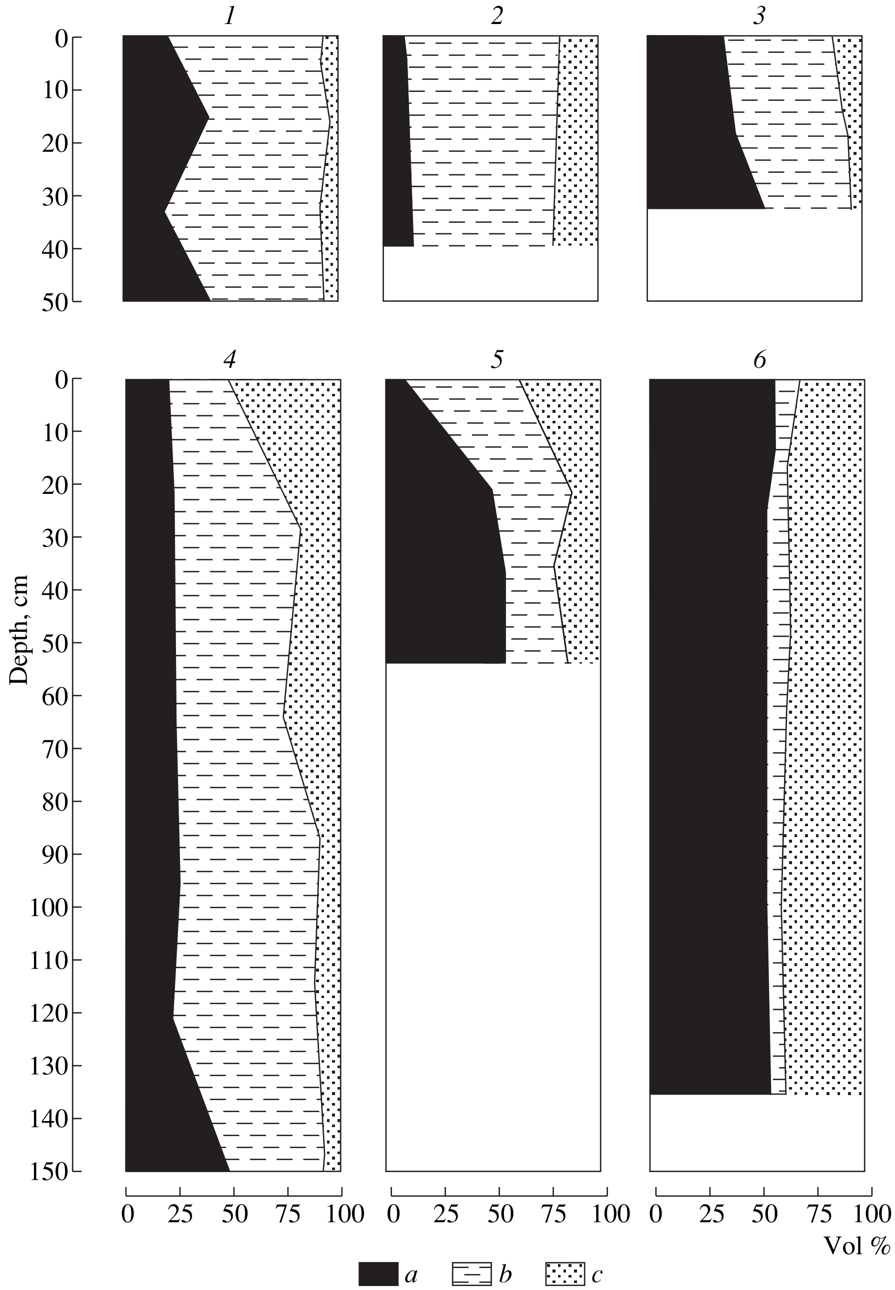
proceeds in relatively stable conditions. In delta areas and on open shores strongly affected by waves, the bulk density of mineral soil horizons exceeds 1.3 g/cm^3 and their field water content is below 35 wt %.

Data on physical properties of different types of Thalassosols (except for maritime meadow soils) are insufficient to make statistically valid conclusions. Therefore, we give the ranges of variations in physical properties of different taxonomic groups of Thalassosols (Table 4). Physical properties of marsh organic soils remain virtually unstudied. At present, we only have data on the bulk density of peaty and humus-accumulative horizons of typical marsh soils. Therefore, this type of Thalassosols is not included in the table.

The lowest values of the bulk density of organic and humus-accumulative horizons are observed in typical marsh soils. Similar horizons of alluvial marsh soils and a peaty (with a considerable admixture of mineral matter) horizon of maritime meadow-swampy soil are characterized by somewhat higher values of bulk density (up to 0.7 g/cm^3). Peat horizons of maritime swampy and meadow-swampy soils have minimal values of the bulk density and solid phase density. At the same time, humus-accumulative horizons of meadow-swampy soils have a bulk density of about 1 g/cm^3. A higher bulk density is observed only in maritime meadow soils (more than 0.5 g/cm^3 in gleyed soils and more than 1.1 g/cm^3 in typical meadow soils). Mineral horizons with the bulk density <1 g/cm^3 are found in heavy-textured typical marsh soils and maritime swampy soils. The highest values of bulk density are registered in mineral horizons of maritime meadow soils.

There is no need to comment on all the data presented in Table 4. However, several facts deserve special consideration. First, we should note that the field moisture, field water capacity, and maximum water capacity of peat horizons in maritime swampy soils are higher than those in peat horizons of marsh soils and meadow organic soils. As was already mentioned, the bulk density and the solid phase density of peat horizons of swampy soils are very low. The porosity of these soils may exceed 90%. These facts attest to different conditions of peat accumulation in the littoral (tidal) zone and in coastal areas outside this zone. This is an additional argument in favor of the separation of maritime and marsh soils.

The water content of marsh and maritime swampy soils in natural conditions exceeds their field capacity; in other words, the relative water content of these soils is above 100%. This fact attests to the influence of groundwater on the full profile of marsh and maritime swampy soils. The relative water content above 100% is also observed in mineral horizons of maritime meadow-swampy soils and in bottom horizons of maritime meadow gley soils. Typical maritime meadow soils have the relative water content below 100% in the full profile.



The proportions between (*a*) solid, (*b*) water, and (*c*) gaseous phases in the profiles of Thalassosols: (*1*) typical marsh, (*2*) maritime swampy (peaty–mucky), (*3*) maritime meadow-swampy moderately deep, (*4*) maritime meadow with peaty–mucky surface horizons, (*5*) maritime deep meadow gley, and (*6*) maritime typical meadow soils.

The total porosity of Thalassosols is rather high: 42–76% in mineral and transitional horizons and 45–82% in humus-accumulative and organic horizons. The aeration porosity of marsh and maritime swampy soils is relatively low, which conditions the development of anaerobic processes. The aeration of maritime meadow-swampy soils and meadow gley soils is sufficiently high in the uppermost horizons and very low in bottom horizons. Typical maritime meadow soils are well aerated to a considerable depth. The proportions between the liquid, solid, and gaseous phases in the profiles of different Thalassosols are shown in the figure.

Data on the vertical distribution of physical properties along the profiles of Thalassosols are given in Table 5. In contrast to the majority of continental soils that display an increase in the bulk density and solid phase density down the profile, the distribution of these physical parameters in the profiles of Thalassosols is less regular. Often, the degree of contrast in physical properties between adjacent soil horizons of Thalassosols is

Table 5. Some physical properties of Thalassosols

Horizon	Depth, cm	Solid phase density	Bulk density	Porosity		Water capacity			Natural water content
				total	aeration	maximum	capillary	field	
		g/cm^3		vol %		wt %			
Typical marsh poorly developed soil									
I	0–6	2.30	0.55	76.1	6.3	137.1	129.0	124.9	126.9
II	6–26	2.50	1.00	60.0	3.2	59.9	57.6	56.0	56.8
TG	26–39	2.23	0.38	83.0	10.5	215.6	199.5	191.2	190.6
IV	39–65	2.60	1.41	45.8	5.2	31.1	29.8	28.4	28.8
Maritime swampy (peaty–mucky) soil									
T1	0–24	1.72	0.15	91.3	17.7	517.9	474.6	431.4	490.4
T2	24–46	1.51	0.17	88.7	18.6	497.4	422.4	386.5	412.7
Typical maritime meadow-swampy moderately deep soil									
AOg	0–15	2.69	0.98	63.6	8.2	64.7	59.5	55.8	56.5
CG	15–22	2.58	1.05	59.3	5.2	53.5	51.2	49.1	51.5
DG	22–36	2.75	1.37	50.2	4.9	35.6	33.8	32.1	33.0
Maritime meadow peaty–mucky soil									
TA	0–7	2.25	0.48	78.7	48.4	134.6	99.5	89.2	63.1
T1g	7–51	2.16	0.61	71.8	17.8	104.4	96.3	92.9	88.5
T2g	51–80	2.23	0.44	80.3	28.2	154.6	138.1	127.0	118.4
T3g	80–107	2.15	0.46	78.6	9.6	159.9	154.0	151.4	150.1
T4G	107–136	2.44	0.48	80.3	13.4	150.2	145.5	142.5	139.5
DG	136–170	2.68	1.33	50.4	9.9	32.7	31.4	29.7	30.4
Deep maritime meadow gley soil									
AT	0–16	2.42	0.68	72.1	28.5	105.0	77.4	70.6	64.6
A1	16–26	2.48	1.20	51.5	11.2	41.0	37.6	33.2	33.6
AC	26–41	2.50	1.39	44.4	19.7	28.4	25.8	20.2	17.8
C1g	41–63	2.65	1.49	43.8	12.3	24.0	23.3	16.6	21.1

very considerable. Typical maritime meadow soils are the most homogeneous ones, even though in them, we see considerable differences in the distribution of physical properties along the soil profile. This is especially true for multilayered and polycyclic varieties of maritime meadow soils.

CONCLUSIONS

(1) Regional peculiarities of the particle-size composition and physical properties of Thalassosols in the Russian part of the coastal zone of the Sea of Japan fall within the range of variations typical of Thalassosols in the other parts of the world.

(2) The particle-size composition of Thalassosols is inherited from parent rocks. It is not subjected to pedogenic alterations. The enrichment of the upper part of some Thalassosols in the clay fraction is explained by the peculiarities of continuing sedimentation process. The character of sedimentation on one hand and the character of pedogenic alteration of sediments, on the other hand, depend on the particular location of a given site in the coastal landscape. The differences between sedimentation processes on open shores subjected to strong wave action, in small lagoons protected from waves, and in the areas outside the tidal zone explain the differentiation of Thalassosols by their particle-size composition.

(3) Different kinds of pedogenic horizons of Thalassosols are characterized by rather specific physical properties. At the same time, the variation in physical properties of Thalassosols is very considerable, which is conditioned by the lithological heterogeneity of soil-forming rocks. The most pronounced distinctions between different types are observed in the groups of organic and humus-accumulative horizons, i.e., within the horizons that manifest the most evident features of pedogenic alterations.

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