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A.N. Omirzakova[1], K.M. Pachikin[1,2]

MINERALOGICAL COMPOSITION OF THE SIEROZEMIC SOILS IN THE FOOTHILL PLAINS OF ZHETISU RIDGE

[1]Kazakh Research Institute of Soil Science and Agrochemistry after U.U. Uspanov, 050060, Almaty, 75 V al-Farabi avenue, Kazakhstan, e-mail: alnomir @ mail.ru

[2]Research Center for Ecology and Environment of Central Asia (Almaty), 050060, Almaty, 75V al-Farabi avenue, Kazakhstan

Abstract. The mineralogical composition of the fine dispersed part of soils of the foothill plains of the Zhetysu Ridge was studied for the first time as part of the assessment of the fertility and current state of soils of agricultural lands of South-Eastern Kazakhstan. For the first time, studies of clay fraction of northern sierozems showed the following mineral composition: mixed-layer illite-smectite formations, hydromica, kaolinite, chlorite, lizardite, and non-clay minerals - highly dispersed quartz and feldspars; meadow-sierozemic soils contain: mixed-layer formations, kaolinite, lyzordite, magnezioarfvedsonit, mica, chlorite, quartz and feldspar.

Key words: northern sierozems, fine-dispersed mineralogy, hydromica, mixed-layer formations, kaolinite, chlorite, quartz.

INTRODUCTION

Sustainable development of Kazakhstan assumes the implementation of measures aimed at preservation and reproduction of soil fertility and prevention of degradation and desertification of agricultural lands.

In this regard, the issues of conducting geographical research in the Almaty region, where agricultural lands of the foothill plains of the Zhetysu Range are located, are of particular relevance. The territory under consideration is composed of thick sediments of loess-like loams, where the main zonal soils are formed: dark chestnut, light chestnut and grey soils. At absolute altitudes in the zone of wedging out of groundwater, intrazonal soils are also formed: meadow-sierozem, meadow, meadow-marsh, and marsh soils [1, 2].

Pre-mountain sierozem soils zone with *sierozem* ordinary northern soils, within the described territory, belongs to the North Tienshan province (Kyrgyz, Trans-Ili, Dzungarian Alatau and Ketmen ranges) and is located at the altitudes less than 850 m.

The mineralogical composition of the dark, light chestnut soils of the foothill plains of the Zhetysu Ridge was studied as part of the assessment of the current state of agricultural land in South-Eastern Kazakhstan [3]. Geochemical and mineralogical studies of the relevant soils of the dry steppes of Central Kazakhstan were previously carried out by the staff of the Institute of Soil Science [4].

Soil minerals serve as a source of plant nutrients; phosphorus, potassium, magnesium, calcium, iron, sulfur, and trace elements enter the solution. Such studies of the soil mineralogical and chemical properties give an idea of the natural reserves of plant nutrients in them and can be indicators of changes in soil processes under the influence of both soil-forming and anthropogenic influences [5, 6]. Thus, according to the well-known scheme of Gorbunov, potassium is contained in feldspars, micas and hydromica, magnesium is contained in biotites, chlorites and montmorillonites, and phosphorus - in apatites, phosphates of potassium, calcium, magnesium, iron, aluminum and organics. Part of the phosphate is in the state of absorption by clay minerals [7].

One of the most important tasks of Kazakhstan's development is the implementation of measures aimed at preservation and reproduction of soil fertility, since the degradation and desertification of land leads to a permanent decline in the return of material resources invested in agricultural production, undermining the republic's food and economic security. These tasks cannot be solved without reliable systematized information, including data on soil spatial distribution and data on basic soil properties (chemical, physicochemical, physical, morphological, and mineralogical).

Northern or Semirechensky sierozems are divided into two subtypes - ordinary and light. The climate of this region is characterized by a warm, wet spring, during which an outbreak of biological activity occurs and a hot, dry summer with a period of biological rest. The vegetation of both subtypes is wormwood-ephemeroid and ephemeroid-wormwood (Artemissia sublessingiana, Poa bulbosa, Carex). Loesslike loams have become widespread as soil-forming rocks. Northern sierozem soils are characterized by low-humus profile - the thickness of humus horizons (A + B) is 35-50 cm. Ordinary normal sierozem soils contain 1.3-2.0 % of humus and 0.08-0.13 % nitrogen in the upper horizon, which quantity gradually decreases (table 1). The low amount of absorbed bases (9-11 mg-eq/100 g) is also characterized by a decrease in the depth of the profile. The absorbing complex is saturated with calcium in the presence of potassium and magnesium. The reaction of soil suspension is alkaline (pH = 8-8.6). Meadow-gray soils are located on the foothill plains of the Dzungar Alatau and are divided into non-saline, solonchak, solonets-solonchak genera. Vegetation - ephemeroid-chiy-wormwood, with feather grass, gorchak, ephemerals. Soil-forming rocks are alluvial layered sandy loams and clay loams. Meadow-gray non-saline soils contain in the upper horizon 0.8-1.3% of humus and 0.08-0.10 % of nitrogen (table 1). The amount of exchangeable bases is low (7-10 mEq/100 g), gradually decreasing in depth. Calcium predominates in absorbed bases, less magnesium, and sodium is present in alkaline soils. The reaction is alkaline (pH = 8.0-8.6) [1, 2].

OBJECTS AND METHODS

This article for the first time presents data on mineralogical study of sierozem soils of the northern and meadow-sierozem soils of the Zhetysu Ridge (Dzungar Alatau).

The following soils of this region were the objects of investigation of the mineralogical composition of the clay fractions:

Section 06/C15 - sierozem northern ordinary irrigated light loamy.

Section 12/C15 - meadow-sierozemic soil non-saline light loamy.

To study the substance composition of the clay fractions of soil of the Zhetysu Ridge, an x-ray diffraction-metric research method was used [8].

X-ray diffraction-metric analysis was performed on an automated diffractometer DRON-3 with Cu_K - radiation, β-filter. Diffractogram shooting conditions: U = 35 kV; I = 20 mA; θ-2θ shooting; 2 degree/min detector. X-ray phase analysis on a semi-quantitative basis was performed on powder samples diffractogram patterns using the method of equal weights and artificial mixtures. The quantitative ratios of crystal phases were determined. The diffraction patterns were interpreted using the ICDD data files: a PDF2 (Powder Diffraction File) database of powder diffractometric data and diffractograms of mineral free of admixtures.

The gross analysis of soil clay fraction was performed by X-ray spectral microanalysis using an electronic probe microanalyzer of the Super-probe 733 brand, JEOL (Japan). Analysis of the elemental composition and photo shootings in various types of radiation were performed using an JNCAENERGY energy dispersive spectrometer (Oxford instruments) in accelerating voltage of 25 kV and a probe current of 25 nA.

Table 1 – Chemical and physic-chemical properties of sierozem and meadow- sierozemic soils

№ sections	Depth, cm	Humus, %	Total nitrogen, %	CO_2, %	Absorbed cations, mg-eq/100 g					Mobile forms, mg / kg			pH
					Ca	Mg	Na	K	Сумма	P_2O_5	K_2O	hydrolyzed nitrogen	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sierozem Ordinary Northern Irrigated Light Loamy													
06/C15)	0-10	1,18	0,112	0,58	5,00	5,00	0,26	0,58	11,34	29,00	510	39,20	7,98
	17-27	1,13	0,112	0,68	8,50	1,50	0,26	0,58	10,84	26,00	500	33,60	7,97
	32-42	0,82	0,112	1,23	8,00	1,80	0,20	0,18	10,13	7,00	200	30,80	8,03
	48-58	0,75	0,084	2,50	8,20	1,70	0,24	0,15	10,39	-	-		8,02
	75-85	-	-	6,13	-	-	-	-	-	-	-		8,13
Meadow-sierozemic soil non-salinized, light loamy													
12/C15	0-9	1,33	0,100	1,00	4,50	2,00	0,22	0,53	7,25	35,00	400	30,80	8,09
	12-22	0,55	0,056	3,16	4,25	1,75	0,26	0,68	6,94	10,00	480	25,20	8,28
	28-38	0,51	0,056	1,84	3,80	2,25	0,30	0,55	6,85	7,00	430	19,6	8,37
	45-55	0,44	0,042	1,87	3,50	2,00	0,19	0,47	6,16	-	-	-	8,45
	75-85	-	-	3,19	-	-	-	-	-	-	-	-	8,31

RESULTS AND DISCUSSION

The gross chemical composition of clay fraction of sierozems and meadow – sierozemic soils is characterized by a high content of sesquioxides and absence of significant changes in the profile (Table 2, 3). The greatest amount of phosphorus, silicon, and alumina oxides is observed in the arable horizon of the studied soils.

Sierozems and meadow-sierozemic soils contain more oxides of silicon, phosphorus, and potassium in the upper horizons. Compared to soil, gross chemical composition of clay fraction of sierozems shows a decrease in the amount of silicon oxide (25.5-35.0 %) and increase in iron and aluminum oxides (5.0-8.5 %), (10.2-14.7 %) (Table 2, 3), respectively. Clay fraction of the studied soils contain more magnesium, which indicates the presence of magnesium-containing minerals – the presence of magnesioarfvedsonite in meadow- sierozemic soil was determined (Table 4). An interesting fact is that in the mineralogical composition of the previously studied dark, and light chestnut zonal soils of the Zhetysu ridge, magnesioarfvedsonite was not found [3]. The relatively low content of calcium oxide in the sludge indicates the opposite - a small amount of calcium-containing minerals. In the clay of the arable horizon, phosphorus and potassium oxides exceed its amount in soil as a whole.

As a result of the X-ray diffractometric study of finely dispersed fractions of sierozems and meadow- sierozemic soils of the Zhungar Ridge, the following distribution pattern of clay minerals was established (Figures 1, 2).

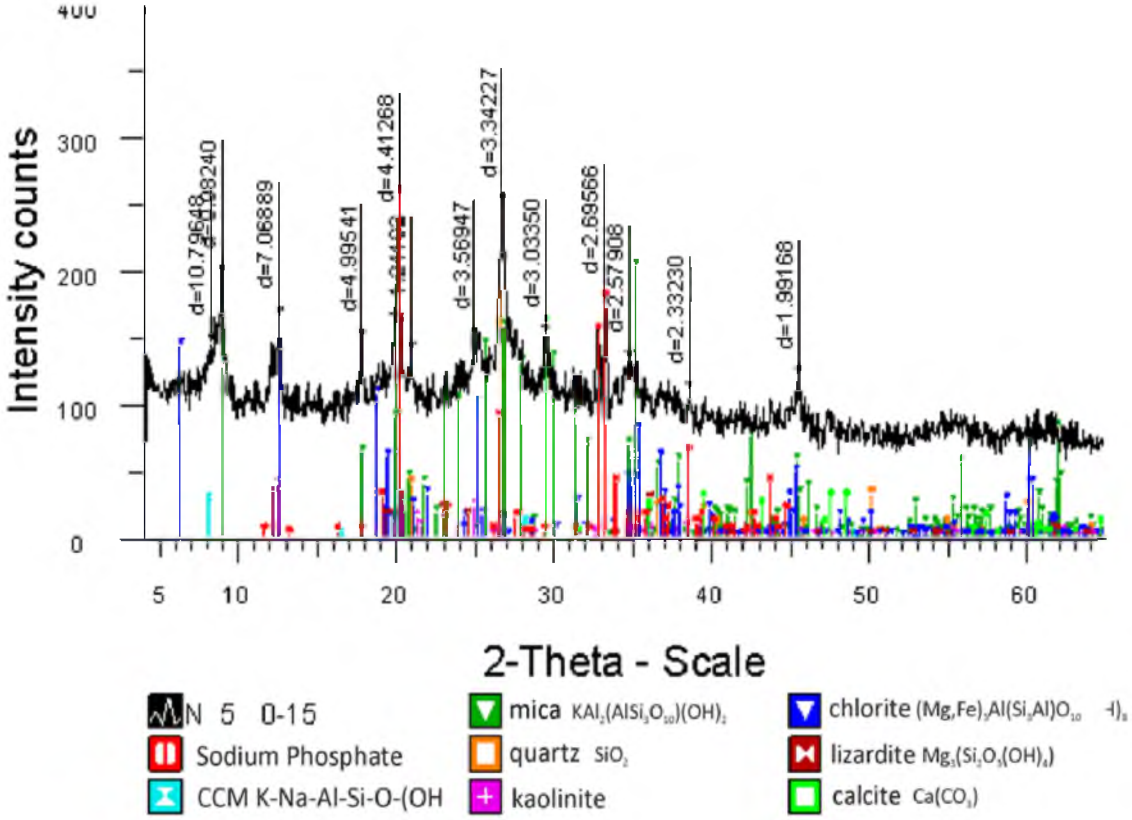

Figure 1 – Diffraction pattern of northern ordinary sierozem (R. 06/C15; depth 0-10 cm)

Table 2 – Gross chemical composition of clay fraction of northern ordinary sierozem (R. 06 / C15)

Depth of section, 0-10 cm												
All results in compounds,%												
Spectrum	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3	Total
Spectrum 1	14,74	2,85	14,40	34,07	18,19	0,60	3,63	3,54	0,38	0,22	7,39	100,00
Spectrum 2	14,15	3,45	14,48	35,46	16,61	0,34	3,76	3,27	0,65	0,23	7,59	100,00
Spectrum 3	11,29	3,11	15,28	37,67	14,33	0,41	4,06	4,51	0,58	0,25	8,50	100,00
Average	13,40	3,14	14,72	35,73	16,38	0,45	3,82	3.78	0,54	0,23	7,83	100,00
Standard deviation	1,84	0,30	0,48	1,82	1,94	0,13	0,22	0,65	0,14	0,01	0,59	-
Max	14,74	3,45	15,28	37,67	18,19	0,60	4,06	4,51	0,65	0,25	8,50	-
Min	11,29	2,85	14,40	34,07	14,33	0,34	3,63	3,27	0,38	0,22	7,39	-
Section depth, 17-27 см												
All results in compounds,%,												
Spectrum	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	TiO_2	CaO	MnO	Fe_2O_3	Total
Spectrum 1	7,98	5,36	14,99	36,27	14,69	0,22	4,51	0,59	6,89	0,15	7,36	100,00
Spectrum 2	6,68	5,95	14,45	35,70	16,65	0,35	5,46	0,71	6,25	0,16	7,65	100,00
Spectrum 3	8,22	5,31	14,77	36,08	15,88	0,24	5,60	0,42	5,64	0,20	7,64	100,00
Average	7,62	5,54	14,73	36,02	15,74	0,27	5,19	0,57	6,26	0,17	7,55	100,00
Standard deviation	0,62	0,23	0,27	0,29	0,51	0,07	0,07	0,15	0,63	0,03	0,16	-
Max	8,22	5,95	14,99	36,27	16,65	0,35	5,60	0,71	6,89	0,20	7,65	-
Min	6,68	5,31	14,45	35,70	14,69	0,22	4,51	0,42	5,64	0,15	7,36	-

Table 3 – Gross chemical composition of clay fraction of meadow-sierozemic soil (R. 12 / C15)

Section depth, 0-9 см											
All results in compounds,%											
Spectrum	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	Fe_2O_3	CI	Total
Spectrum 1	18,65	2,65	11,36	28,94	22,77	0,16	2,91	6,78	0,36	5,64	0,14	100,00
Spectrum 2	17,51	3,06	11,87	30,41	20,63	0,50	3,26	6,71	0,44	5,78	0,09	100,00
Spectrum 3	18,40	2,71	11,89	29,38	21,43	0,35	3,22	6,24	0,33	5,21	0,09	100,00
Average	18,19	2,81	11,71	29,58	21,61	0,34	3,13	6,58	0,38	5,64	0,11	100,00
Standard deviation	0,60	0,22	0,31	0,76	1,08	0,17	0,19	0,30	0,05	0,38	0,03	
Max	18,65	3,06	11,89	30,41	22,77	0,50	3,26	6,78	0,44	5,94	0,14	
Min	17,51	2,65	11,36	28,94	21,43	0,16	2,91	6,24	0,33	5,21	0,03	

Section depth, 12-22 см										
All results in compounds,%										
Spectrum	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	Fe_2O_3	CI	Total
Spectrum 1	12,81	3,36	14,99	36,27	13,69	3,51	6,89	0,59	7,74	0,15	100,00
Spectrum 2	13,68	3,95	14,45	36,70	14,65	3,46	6,25	0,71	5,99	0,16	100,00
Spectrum 3	14,22	3,31	15,77	36,58	13,88	3.60	6,64	0,50	5,30	0,20	100,00
Average	13,62	3,21	15,73	36,02	14,07	3,52	7,26	0,57	5,82	0,18	100,00
Standard deviation	0,62	0,23	0,27	0,29	0,51	0,07	0,63	0,15	0,16	0,03	
Max	14,22	3,36	14,99	36,27	14,65	3,60	6,89	0,71	5,49	0,20	
Min	12,98	2,95	14,45	35,70	1,69	3,46	5,64	0,42	5,16	0,15	

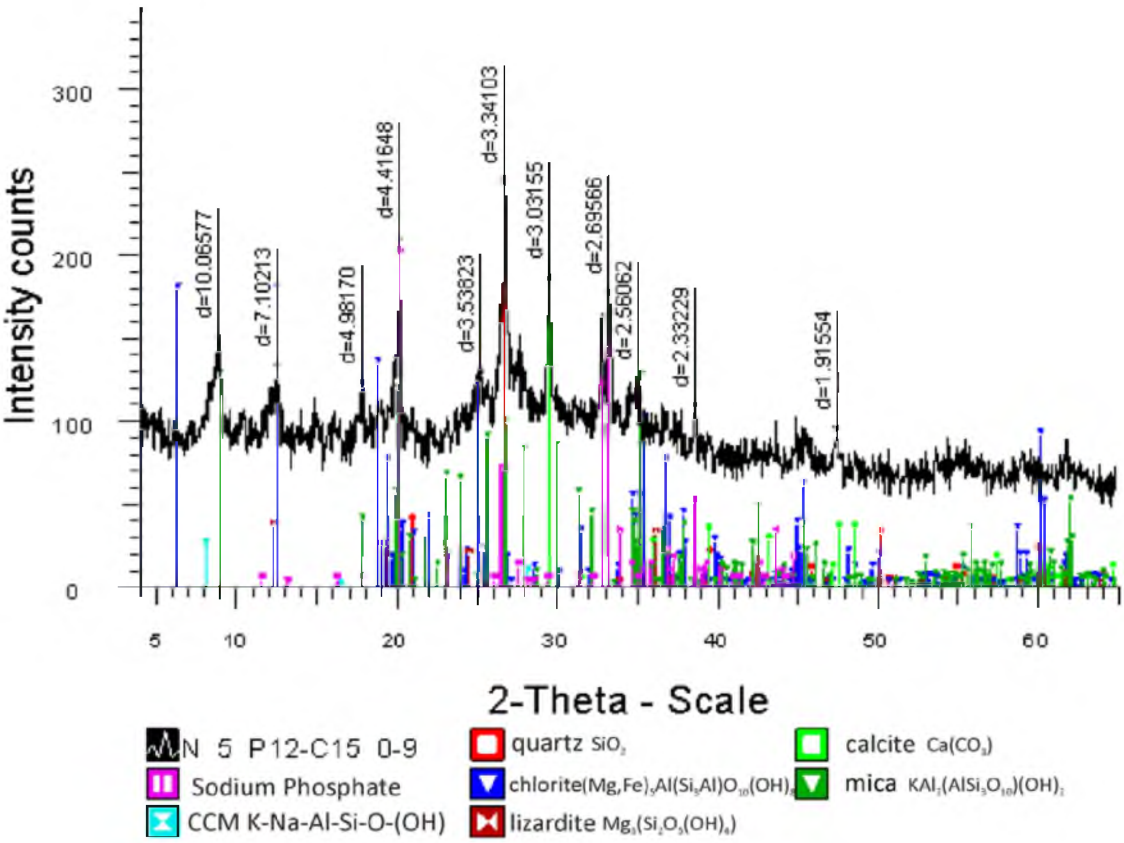

Figure 2 – Diffractogram of meadow-gray soil (R.12 / 15; depth 0-9 cm)

The mineralogical composition of the clay fractions of the studied soils consists of disordered mixed-layer (illite-smectite) formations, hydro-mica, trioctahedral chlorite, lizardite, magnesio-arfvedsonite, kaolinite, ferroactinolite, feldspar and quartz (Table 4). The differentiation of the above minerals by the profile of the studied soils is small and synchronous in terms of the sludge content. Transformational changes of trioctahedral and accumulation of dioctahedral minerals of clay fraction, as well as the formation of phosphates, as a result of repeated fertilization, occur most intensively in the upper horizons of the studied soils (Table 4). It is well known, that the replacement of potassium in hydromica can lead to the formation of swelling packets and, as a result, minerals with stable and labile packets are formed, i.e. mixed-layer minerals (MLM) –mica – montmorillonite [7], which are widely distributed in sedimentary rocks of various types.

Potassium-containing hydromica minerals are present in varying quantities in sierozems and meadow- sierozemic soils and a comparison of total potassium in sludge in the upper and lower horizons of the studied soils showed an accumulation of potassium in the upper horizons, which is probably related to the process of their clayzation. So, in the composition of clay minerals of the finely dispersed fraction of these soils, the structure-swelling components are involved, in which interpacket potassium is more mobile than in hydrofluoric structures [9]. Magnesium-rich minerals of montmorillonite and chlorite groups and their mixed-layer formations increase in the lower and middle horizons.

Table 4 – Mineralogical composition of clay fraction of northern sierozem and meadow-sierozemic soil

№пп	Depth , см	Content of clay, fr.< 1mkm	MLM	Hydromica	Chlorite + kaolinite	Lizardite	Sodium Phosphate	Calcite	Quartz	Epidote	Feldspar	Magnesioarfvedsonite	Ferroaktinolit
Sierozem northern ordinary irrigated light loamy (R. 06 / C15)													
1	0-10	12,131	17,4	18,9	12,9	5,9	31,5	5,6	7,8	-	-	-	-
2	17-27	12,920	15,7	15,2	15,7	-	35,2	7,5	8,7	-	2.0	-	-
3	32-42	14,173	16,8	9,4	15,5	14,1	10,3	16,8	14,9	2.2	-	-	-
4	48-58	13,368	15,4	11.9	16,8	15,4	-	19,0	12,7	3,5	5,3	-	
5	75-85	12,563	18,5	11,6	15,1	13,0	-	19,5	12,1	4,8	5,4	-	-
Meadow- sierozemic non-salinized, light loamy on loess-like loams (R. 12 / C15)													
1	0-9	12,080	14,7	16,8	9,5	7,8	32,8	7,9	-	10,4	2,1	-	-
2	12-22	14,877	9,3	9,6	8,7	-	30,5	4,5	5,2	15,2	2,5	19,0	
3	28-38	14,455	10,9	7,9	12,6	7,6	-	7,7	5,1	14,8	5.0	12,9	15,5
4	45-55	12,480	14,6	7,7	18,0	5,0	-	8,3	8,4	12.5	6,1	11,5	7,9
5	75-85	11,259	-	-	-	-	-	-	-	-	-	-	-

The appearance of the montmorillonite group in the upper horizons is probably associated with the transformation of hydromica as a result of prolonged leaching and the release of potassium from mica and hydromica grids. In the works of B.P. Gradusov, N.P. Chizhikova, Plakhina [10] in particular, clay minerals were explored for possible potassium mobilization during soil formation and provision of plants with this element to increase their resistance to weathering and soil formation agents: 1) biotite, phlogopite, 2) mixed-layer biotites (phlogopites) - vermiculites, in particular, hydrobiotites, 3) glaconitites and mixed-layer mica-smectites, 4) muscovites, sericites, dioctahedric hydromica, 5) orthoclase, microcline.

Along with hydromicalization in meadow- sierozemic soils, an increase of magnesia in the depth due to the iron index is observed. It is expressed in a decrease of molecular ratio of iron to magnesium down in the profile, even when the absolute iron content in the clay fraction increases in depth, but less significantly than magnesium.

Highly dispersed clay minerals, defined in the profile of these soils, regulate the distribution of the elements of applied fertilizers, which are fixed in their crystal lattices (Figure 1).

The theoretical basis for research, where we studied the reserves of potassium, phosphorus and other elements in the soil was the provision proposed N.I. Gorbunov [7], on the division of the ash elements of soil into direct, close and potential, depending on chemical and mineralogical composition and dispersion of soil.

During the study of the mineralogical composition of other zonal (dark, light chestnut) soils of the Zhetysu Ridge region, it was shown that most of the total potassium reserves is accumulated in the potential and in the close reserve [3]. The same trend can be seen in this case - where the northern gray and meadow gray soils are provided with direct and close potassium reserves.

To carry out developments related to the solution of practical problems of land management, it is necessary to have reliable and qualitative data on soil characteristics of the region, the structure of soil surface and its transformation associated with the action of natural and anthropogenic factors.

CONCLUSION

1. For the first time the studies of clay fraction of northern sierozems and meadow-sierozemic soils of foothill plains of Zhetysu ridge- showed the following mineralogical composition in the northern sierozem: mixed-layer hydromica-smectite formations, hydromica, kaolinite, chlorite, lizardite and non-clay minerals- highly dispersed silica and field spars; meadow-sierazem soils contain: mixed-layer formations, magnesioarfvedsonite, kaolinite, licorite, mica, chlorite, ferroactinolite, quartz and feldspar.

2 Northern sierozems and meadow-sierozemic soils are characterized by the content of a significant amount of potential and close reserves of potassium, conditioned by hydromica nature of highly dispersed minerals and presence of feldspars and mica.

The results of the research will contribute to set the control over the concentration and changes of the main plant nutrients associated with land use for the development of schemes for the sustainable development of the territory and planning the need for mineral fertilizers for the rational land use.

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ТҮЙІН

Ә.Н. Өмірзақова[1], К.М. Пачикин[1,2]

ЖЕТІСУ ЖОТАСЫНЫҢ ТАУ ЕТЕГІ ЖАЗЫҚТАҒЫ СҰР ТОПЫРАҚТЫҢ МИНЕРАЛОГИЯЛЫҚ ҚҰРАМЫ

[1]Ө.О. Оспанов атындағы Қазақ топырақтану және агрохимия ғылыми зерттеу институты, 050060, Алматы қ., әл Фараби даңғылы, 75 В, Қазақстан, e-mail: alnomir@mail.ru

[2]Орталық Азия экология және қоршаған орта ғылыми-зерттеу орталығы (Алматы), 050060, Алматы қ. әл-Фараби даңғылы, 75В, Қазақстан

Жетісу жотасының тау етегіндегі жазық топырақтардың ұсақ бөлігінің минералогиялық құрамы алғаш рет Оңтүстік-Шығыс Қазақстанның ауыл шаруашылық жерлерінің құнарлылығын және ағымдағы жай-күйін бағалау шеңберінде зерттелді. Солтүстік сұр топырақтың алғаш рет жүргізілген зерттеулері ылайлы фракцияның келесі минералдық құрамамын көрсетті: ретсіз аралас қабатты иллит-смектитті түзілімдері, гидрослюда, каолинит, хлорит, лизартит және ылайсыз минералдар- ұнтақталған кварц, далалық шпаттар; сұр-шалғын топырақ құрамы: ретсіз аралас қабатты түзілімдер, каолинит, лизордит, магнезиоарфведсонит, слюда, хлорит, кварц және далалық шпаттар.

Түйінді сөздер: солтүстік сұр топырақ, ұсақ дисперсті минералогия, гидрослюда, ретсіз аралас қабатты түзілімдер, каолинит, хлорит, кварц.

РЕЗЮМЕ

А.Н. Омирзакова[1], К.М. Пачикин[1,2]

МИНЕРАЛОГИЧЕСКИЙ СОСТАВ СЕРОЗЕМНЫХ ПОЧВ ПРЕДГОРНЫХ РАВНИН ЖЕТЫСУСКОГО ХРЕБТА

[1]Казахский научно-исследовательский институт почвоведения и агрохимии имени У.У. Успанова, 050060, г. Алматы, проспект аль-Фараби, 75В, Казахстан, e-mail: alnomir@ mail.ru

[2]Научно-исследовательский центр экологии и окружающей среды ЦА (Алматы), 050060, г. Алматы, пр. Аль-Фараби, 75 В, Казахстан

Минералогический состав тонкодисперсной части почв предгорных равнин Жетысуского хребта был впервые исследован в рамках проекта по оценке современного состояния сельскохозяйственных земель Юго-Восточного Казахстана. Впервые проведенные исследования илистой фракции почв сероземов северных показал следующий минералогический состав: смешанослойные иллит-смектитовые образования, гидрослюда, каолинит, хлорит, лизардит, и неглинистые минералы- высокодисперсный кварц и полевые шпаты; лугово-сероземные почвы содержат: смешанослойные образования, каолинит, лизордит, магнезиоарфведсонит, слюду, хлорит, кварц и полевые шпаты.

Ключевые слова: сероземы северные, тонкодисперсная минералогия, гидрослюда, смешанослойные образования, каолинит, хлорит, кварц.