GENESIS, DEVELOPMENT, AND CLASSIFICATION FOR SOME SELECTED SOILS AT KURDISTAN REGION, NORTH OF IRAQ

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ABSTRACT

The study area was located in the North of Iraq. Five sites were selected that have formed from the limestone parent material. One pedon dug in each site and was divided into a number of horizons. Thirty-five soil samples were collected for physical and chemical analyses. The climate of study sites were similar to the Mediterranean Sea climate which is hot dry in summer and cool humid in winter. The mean of annual precipitation, varies from one site to another. Studied soils classified as Mollisols, Inceptisols, Vertisols, and Aridisols. Study soils were relatively high clay content and its content at the surface horizons is lower than it at subsurface horizons, and soil texture was ranged between clayey to loamy, the high value for clay content indicates to soil development. Fine clay/Coarse clay ratio showed that the pathway of fine clay similar to the pathway of total clay. CEC values increased with increasing clay. Organic matter was high in the surface horizons and decrease with depth. The following pedogenic processes occurred in study soils loss, gain, leaching, illuviation, eluviation, alkalization, humification, lessivage, desalinization, calcification, decomposition, and synthesis.

Key words: Fine clay, coarse clay, pedogenic processes, lessivage, humification, calcareous

نشوء وتطور وتصنيف بعض الترب المختارة في أقليم كردستان شمال العراق

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المستخلص

تقع منطقة الدراسة في شمال العراق وأختيرت خمسة مواقع ذات مادة أصل كلسية. تم حفر بيدون في كل موقع وقسم الى عدد من الافاق التشخيصية. جمعت خمسة وثلاثون عينة تربة للتحليلات الفيزيائية والكيميائية. مناخ مناطق الدراسة كان مشابها لمناخ البحر المتوسط والذي كان حار جاف صيفا وبارد رطب شتاءا. معدل السواقط الموسمية كان مختلفا من موقع الى اخر. صنفت ترب الدراسة الى ترب المولسول والانسبتيسول والفيرتيسول والأريديسول. ترب الدراسة كانت ذات محتوى طيني عالي نسبيا وكان محتواه عند السطح اقل منه في الافاق تحت السطحية وتراوحت نسجة ترب الدراسة بين النسجة الطينية والمزيجية. المحتوى العالي من الطين اشار الى تطور ترب الدراسة. نسبة الطين الناعم الى الطين الخشن اظهر بأن مسار الطين الناعم مشابه لمسار الطين الكلي . قيم السعة التبادلية الكاتيونية ازداد مع زيادة محتوى الطين. المادة العضوية كانت عالية في الافاق السطحية وانخفضت مع العمق. العمليات البيدوجينية التالية حدثت في ترب الدراسة الفقد , الكسب, الغسيل , الأكتساب البيدولوجي , الفقدان البيدولوجي ,تكوين الدبال, النقل الميكانيكي , عكس التملح , التكلس , التحلل , والتصنيع.

الكلمات المفتاحية: الطين الناعم , الطين الخشن , العمليات البيدوجينية , النقل الميكانيكي , التدبل , التكلس

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INTRODUCTION

Pedogenic processes, particularly leaching processes, are essential to soil formation; the climate is of paramount importance in this regard, particularly rainfall and temperature (3). The stability of calcium carbonate and non-transfer or washing to the lower horizons in the soil because of the relatively low solubility, especially that calcium carbonate minerals of minerals that are concentrated in the dry areas and semi-dry as deposited metal in the case of lack of rain and increase its deposition when evaporation is higher than the amount of rain (2). Lessivage, also called argilluviation, consists of a substantial vertical transfer of fine particles ranging in size from less than 2 µm to 10 µm (9) from a superficial horizon, called the eluviated horizon or E-horizon to another horizon called the illuviated or B horizon (25). Nevertheless, soil features are formed by pedogenesis acting on anthropogenic materials and a wide variety of (bio) geochemical processes are involved in their formation, including the bacterial breakdown of the organic material, as well as adsorption, precipitation, humification and mineralization (22). The accumulations of clays and oxides reflect the stage of pedogenic development (6). In line with this, chemical weathering and physical erosion should be coupled to the degree that mineral weathering rates depend on the availability of fresh mineral surfaces with high reactivity (17). Changes in the weathering index with depth commonly are gradual or continuous, steady and systematic for homogeneous parent rocks, reflecting continuous leaching of elements as weathering progresses on initially homogenous parent material, similar patterns have been reported in at least some instances of saprolitic profiles developed on deformed gneisses and schists (23). Illuviation of clay is considered to be an important pedogenic process in soil formation. Clay accumulation through illuviation in soils is an established fact since the presence of illuvial clay horizon known as argillic. Horizon has been recognized as a subsurface diagnostic criterion to group soils at order level in Soil Taxonomy (20). However, decomposition of organic matter and weathering of primary minerals are possible sources of exchangeable cations. The positive correlation between clay content and soil CEC may be due to increase in clay causes increase in negative charge because clay particles regards as a source of negative charge (1), Soil organic matter is considered to be a key influence of soil quality because of its role on properties and processes in soils (13). On the other hand, Levine and Ciolkosz (15) proposed a clay accumulation index which yielded a good relationship between age and clay accumulation in (Bt) horizons. The argillic horizons are generally subsurface horizons with significantly greater percentages of phyllosilicate clay than it in surface soil horizons, the increase in clay being attributed to the illuviation process (19). The occurrence of an argillic horizon in calcareous parent material of an arid to semiarid climate could point to a palaeoprocess in stable geomorphologic conditions (10). There was no significant difference in the mean values of sand, silt and clay between rhizosphere of tree species and that of bulk soil, The surfaces and edges of mica were less affected by the weathering processes, and the edges weathering was identified with different thickness of weathered edges related to the intensity of weathering that were exposed (4). This study aimed to explain soil formation depending on the pedogenic processes, specify soil development, and classification of study soil according to the key to soil taxonomy as adopted for use by USDA. We try through this study to answer questions about how soil development depending on the particular criteria and measurement soil properties that will be used in order to determine soil evolution in the study area because there are very few studies was conducting in this field.

MATERIALS AND METHODS

Study area: The study area is located in the Kurdistan region, North of Iraq and five sites were selected that have soils formed from limestone parent material (Semeel, Fayde, Gerderash, Alton-Kopri, and Wermawa) (Table.1 and Figure 1). The climate of study sites is similar to the Mediterranean Sea climate which is hot dry in summer and cools humid in winter. The mean of annual precipitation, varies from one site to another, in Semeel (503.53) mm, Fayde (293.83) mm, Gerderash (371.08) mm, Alton-Kopri (281.87) mm and Wermawa (723.42) mm.

Table 1. GPS reading of pedons in studied sites

Site	Latitude [N]	Longitude [E]	Elevation [m]
Duhok (Semeel)	**36° 51' 34"**	**42° 51' 56"**	**700**
Mosul (Fayda)	**36° 42' 25"**	**42° 59' 17"**	**376**
Erbil (Gerderash)	**36° 06' 35"**	**44° 01' 37"**	**419**
Kirkuk (Alton-Kopri)	**36° 39' 00"**	**44° 25' 00"**	**500**
Sulaimani (Wermawa)	**35° 20' 20"**	**45° 39' 44"**	**535**

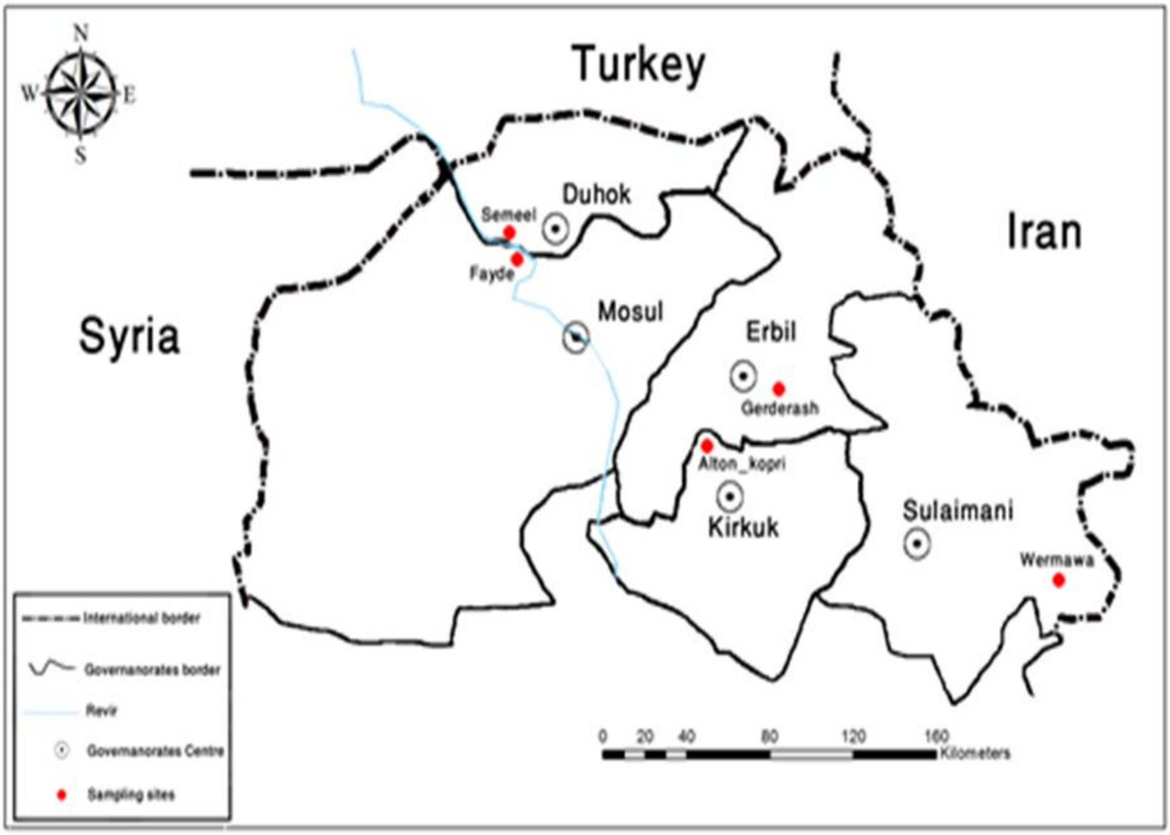

Figure 1. Map of northern Iraq show the study sites

Field work and preparation of soil samples

Soil samples were collected from five sites in the Kurdistan region, northern Iraq, by digging one pedon in each site (5 pedons). Depending on soil morphological properties, each pedon was divided into a number of horizons according to soil survey staff (21), and thirty-five soil samples were collected, ground and sieved with using (2) mm sieve, soil samples were air-dried in order to prepare it for physical and chemical analyses

Laboratory analysis

Particle size distribution was determined by the hydrometer method as showed by Klute (14). Bulk density was determined as described by Black (7). The total porosity of soil samples was calculated according to Danielson and Sutherland (8). Fractionation of total clay and the coarse clay was separated from fine clay by centrifugation with according to Jackson (12). Soil pH and EC measured in (1:1) soil water suspension by using pH- meter and EC- meter (18). Total carbonates were measured by the calcimeter apparatus. Soil organic matter was determined by wet combustion (24), and Cation exchange capacity measured depending on the method of Polemio and Roads method (16).

RESULTS AND DISCUSSION

Physical and chemical properties

The results of the particle size distribution indicated a relatively high clay content of all the soil samples and its content at the surface horizons is lower than it at subsurface horizons for all pedons. On the other hand, the distribution of silt particles has a reverse pattern of clay content that was decreased with depth as a result of alluvial deposits while the sand content has different patterns of distribution in all studied pedons. Commonly, soil texture was ranged between clayey and loamy. Soil bulk density increased with depths except for the pedon (2) at the Fayde site, which was decreased with depth. The highest value of bulk density was (2.18 Kg m^{-3}) in the deep horizon (C) of pedon (5) at Wermawa site, this may be due to increasing clay content, which acts to fill the spaces between pores, addition to increase the bonding strength between the soil particles and increase the values of bulk density. Concurrently, the high porosity values of surface horizons as a result of high decomposition of organic matter and caused the good aggregation of the soil structure in contrast to the low porosity values in subsurface horizons, resulting from mechanical migration for clay (lessivage) from upper horizons to subsurface soil horizons. The high porosity in surface soil horizons and low porosity in subsurface horizons indicate increasing soil development (Table, 2). The values of CEC ranged between (10.3- 27.7 Cmolec kg^{-1}) and the Cation exchangeable capacity values increased with increasing clay content and the highest value was (27.7 Cmolec kg^{-1}) in pedon (5) at Wermawa site in (Bk1) horizon which has clay content (625.3 g kg^{-1}), and this may be due to the lessivage process that was happened in this pedon with a high amount of clay content, and the clay particles are small size, that has a high specific surface area, therefore can be adsorbed high amount of cations on its surfaces, in turn, causes high CEC values whereas the lowest value of CEC was (10.3 Cmolec kg^{-1}) found in the surface horizon (Ap) in pedon (3) at Gerderash site which has clay content (184.8 g kg-1). All studied pedons are exhibited a similar trend in pH value with increasing depth that was ranged (7.8-8.9). The surface horizons had lower pH values than the subsurface horizons because of has relatively high organic matter content. Similarly, the pH values of the studied soils were slightly alkaline as a result of increasing calcium carbonate and pH tends to rise slightly with increasing depth. Generally, studied soils were non- saline and low EC values because of were derived from limestone parent material and consider calcareous soils. The low content of soluble salts was attributed to the desalinization process as affected by rainfall and existing of calcium carbonate (Table, 3). The amount of organic matter in studied soil samples ranged between (0.68-23.1 g kg^{-1}), and the results indicated that the amount of organic matter was high in the surface horizons and decrease with depth; this is due to the accumulation of a high amount of plant residuals (litter) at the upper part of the soil, and increasing organisms activity in the biosphere at roots zone which in turn caused decomposition of litter and increasing humified organic matter (humus) in the surface horizon for soil, particularly at optimum soil moisture regime and optimum soil temperature regime, hence, it can be concluded that the humification process is closely related with (A) horizon in studied soils. Total carbonates content values were ranged between (84-320 g kg^{-1}), the highest value was found in the buried horizon (Ab1), in pedon (3) at Gerderash site, it may be due to the origin of parent materials, whereas the lowest value of carbonates showed at Semeel site because of high precipitation amount which led to leaching and translocation of carbonates out of soils body. Studied soils consider calcareous and have a high content of carbonate minerals as a result of the calcification pedogenic process, in turn, these soils had a high buffering capacity (Table, 3).

Table 2. Physical properties of studied soils

Site	Pedon No.	Depth (Cm)	Horizon	PSD* ($g\ kg^{-1}$)			Texture	Bulk Density ($Mg\ kg^{-1}$)	Fine clay / Coarse clay	Porosity (%)
				Sand	Silt	Clay				
Semeel	1	0- 12	Ap	97.7	405.0	497.3	Silty Clay	1.40	0.24	47.17
		12- 30	A	117.7	357.5	524.8	Clay	1.63	0.20	38.49
		30- 55	Bt1	110.2	297.5	592.3	Clay	1.86	0.22	29.81
		55- 95	Bt2	67.7	332.5	599.8	Clay	1.68	0.38	36.60
		95- 150	Ck	107.7	267.5	624.8	Clay	1.89	0.48	28.68
Fayde	2	0- 6.5	Ap	127.7	532.5	339.8	Silty Clay Loam	1.76	0.15	33.58
		6.5- 18.5	A1	115.2	470	414.8	Silty Clay	1.87	0.28	29.43
		18.5- 65.5	A2	65.2	470	464.8	Silty Clay	1.69	0.44	36.23
		65.5- 90.5	A3	40.2	395	594.8	Clay	1.68	0.49	36.60
		90.5- 115.5	Btk1	65.2	457.5	477.3	Silty Clay	1.69	0.61	36.23
		115.5- 140.5	Btk2	40.2	437.5	522.3	Silty Clay	1.67	0.42	36.98
		140.5- 200	Ck	45.2	325	629.8	Clay	1.61	0.41	39.25
Gerderash	3	0- 7	Ap	475.2	340	184.8	Loam	1.62	0.66	38.87
		7- 16	E	440.2	362.5	197.3	Loam	1.61	0.54	39.25
		16- 57	B	467.7	325	234.8	Loam	1.48	0.55	44.15
		57- 88	Ck	467.7	305.2	229.8	Loam	1.76	0.88	33.58
		88- 91	G**	-	-	-	-	-	-	-
		91- 97	Ab1	477.7	302.5	219.8	Loam	1.85	0.39	30.19
		97- 137	Ab2	355.2	377.5	267.3	Silty Loam	1.64	0.34	38.11
		137- 165	Ab3	280.2	390	329.8	Silty Loam	1.65	0.36	37.74
		165- 185	Bb	255.2	390	354.8	Silty Loam	1.61	0.33	39.25
		185+	Cb	325.2	365	309.8	Clay Loam	1.85	0.77	30.19
Alton-Kopri	4	0- 8.5	Ap	175.5	465	359.8	Clay Loam	1.77	0.39	33.21
		8.5- 20	A	225.2	407.5	367.3	Clay Loam	1.70	0.49	35.85
		20- 54	Btk	272.7	327.5	399.8	Clay Loam	1.88	0.65	29.06
		54- 101	Bk	325.2	345	329.8	Clay Loam	1.50	0.75	43.40
		101- 158	B´tk	290.2	375	334.8	Clay Loam	1.90	1.03	28.30
		158+	Ck	170.2	412.5	417.3	Silty Clay	1.81	1.34	31.70
Wermawa	5	0- 20	Ap	70.2	400	529.8	Silty Clay	1.58	0.16	40.38
		20- 45	A1	45.2	400	554.8	Silty Clay	1.70	0.22	35.85
		45- 61	A2	45.2	325	629.8	Clay	1.61	0.44	39.25
		61- 76	Bt	20.2	357.5	622.3	Clay	1.88	0.40	29.06
		76- 104	Bk1	20.2	354.5	625.3	Clay	1.89	0.49	28.68
		104- 141	B k2	7.4	404.8	587.8	Silty Clay	1.70	0.45	35.85
		141- 173	Btk	7.4	379.8	612.8	Clay	2.10	0.46	20.75
		173- 222	Cca	20.2	367	612.8	Clay	2.18	0.35	17.74

Table 3. Chemical properties of studied soils

Site	Pedon No.	Depth (Cm)	Horizon	Total Carbonate (g kg^{-1})	CEC (Cmole$_c$. kg^{-1} soil^{-1})	pH	EC (dS m^{-1})	O.M (g kg^{-1})
Semeel	1	0- 12	Ap	195	24	7.8	0.6	23.1
		12- 30	A	155	25.6	8.2	0.1	16.9
		30- 55	Bt1	84	25.7	8.6	0.12	12
		55- 95	Bt2	150	23.51	8.6	0.1	10.1
		95- 150	Ck	156	25.06	8.7	0.13	8.2
Fayde	2	0- 6.5	Ap	181.4	16.1	7.9	0.4	21.5
		6.5- 18.5	A1	180.7	16.04	8.4	0.13	15.06
		18.5- 65.5	A2	180	15.3	8.5	0.1	8.6
		65.5- 90.5	A3	193	17	8.8	0.3	8.6
		90.5- 115.5	Btk1	236	17.49	8.8	0.26	2.2
		115.5-140.5	Btk2	244	18	8.9	0.4	1.3
		140.5-200	Ck	187	19.6	8.7	0.1	0.86
Gerderash	3	0- 7	Ap	287	10.3	8.6	0.34	10.1
		7- 16	E	300	12.2	8.8	0.08	9
		16- 57	B	309	11.08	8.8	0.09	18.2
		57- 88	Ck	310	12	8.62	0.08	3.7
		88- 91	G*	-	-	-	-	-
		91- 97	Ab1	320	14.6	8.64	0.06	0.68
		97- 137	Ab2	312	14.6	8.61	0.1	3.7
		137- 165	Bb3	260	12.82	8.7	0.06	1.44
		165- 185	Bb	272	13.76	8.7	0.12	0.68
		185+	Cb	280	16.04	8.8	0.18	3.09
Alton-Kopri	4	0- 8.5	Ap	216.8	20	7.8	0.6	11.7
		8.5- 20	A	220	18.5	8	0.4	4.1
		20- 54	Btk	260	18.9	8	0.4	3.4
		54- 101	Bk	254	20.2	8.6	0.31	2.7
		101- 158	B´tk	240	16	8.59	1.1	2.15
		158+	Ck	260	15.88	8.5	0.35	0.86
Wermawa	5	0- 20	Ap	192	19	7.8	0.4	10.8
		20- 45	A1	190	26	8.2	0.3	13.3
		45- 61	A2	162	24	8.3	0.1	2.58
		61- 76	Bt	130	23.3	8	0.1	1.72
		76- 104	Bk1	250	27.7	8.5	0.4	1.72
		104- 141	Bk2	280	20.2	8.6	0.35	0.86
		141- 173	Btk	267	22.84	8.6	0.4	0.68
		173- 222	Ck	280	23.6	8.7	0.1	0.68

Clay distribution

The results indicated to increase the clay content with increasing depth and this may be due to clay formation or lessivage process as a result of leaching. The highest value of clay (629.8 g kg^{-1}) found in the underlying horizons (Ck) and (A2) in pedon (2) and (5) at Fayde and Wermawa sites respectively, and the lowest value (184.8 g kg^{-1}) was found in the surface horizon (Ap) in pedon (3) at Gerderash site. The increase in clay content in underlying horizons may be due to the parent material of studied soils (Table, 2). Generally, the high values of clay content indicate to soil development and the clay content increased towards subsurface horizons of soil pedon as a result of mechanical migration of fine soil particles as a result of increasing precipitation in study sites, correspondingly clay content increased with depth in the studied pedons; this is due to leaching process as a result of the rainfall effect. On the other hand, in pedon (3) at Gerderash site the leaching of clay includes two stages, in the first stage accumulation of clay content at depth (100) cm at gravel layer, in the second stage clay translocate as a result of leaching process in buried soil and increasing accumulation of clay content in subsurface horizons of studied pedon at Gerderash site (Figure, 2).

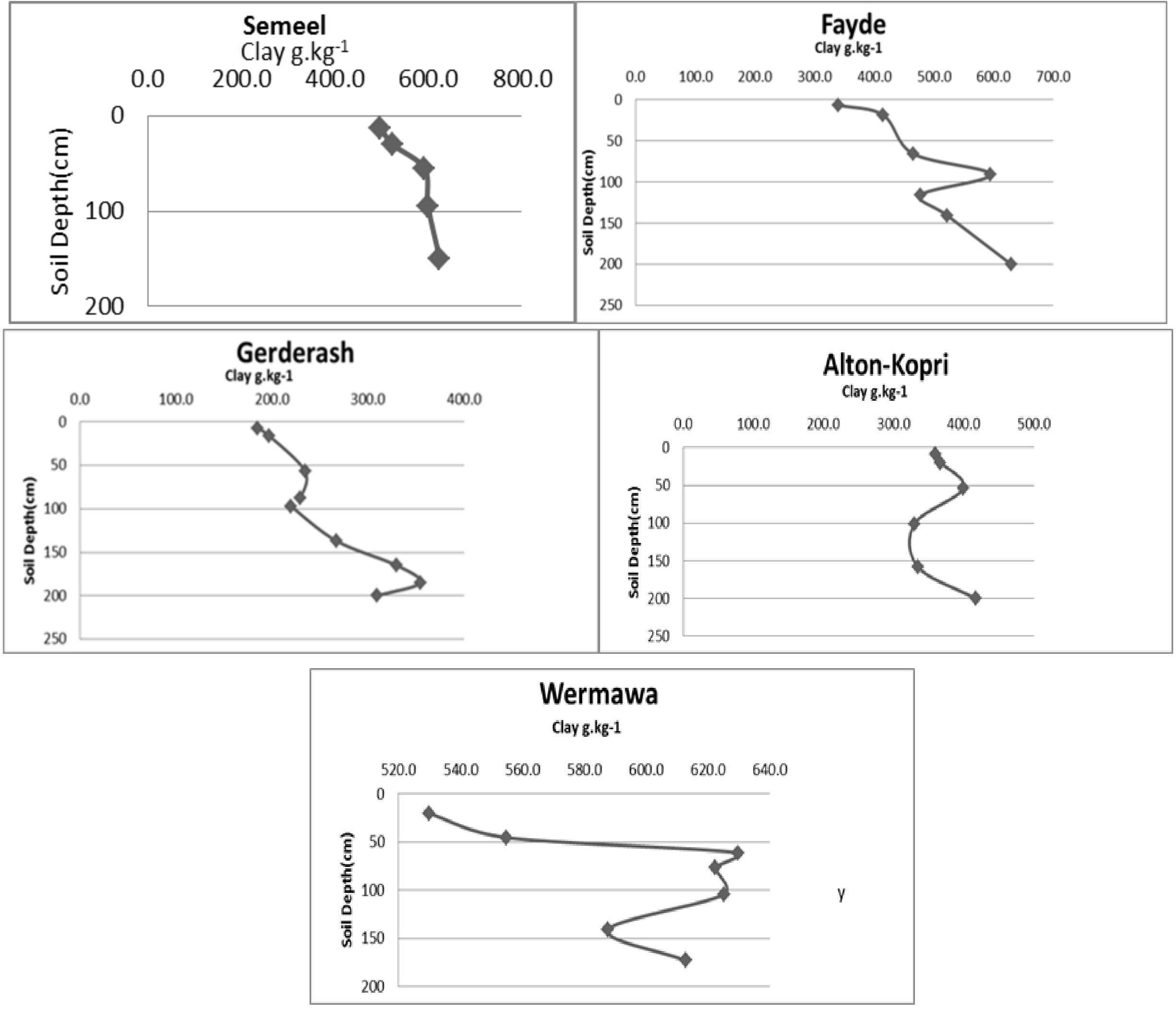

Figure 2. Vertical distribution of clay in studied soil pedons

Fine clay/Coarse clay

The ratio of (Fine clay/Coarse clay) was used as an indicator of soil development because of clay particles became finer with less weathering for soil particles. Results of (Fine clay/Coarse clay) ratio were ranged between (0.15-1.34), the highest value was noticed in the lower horizon (Ck) in pedon (4) at Alton-Kopri site (1.34), while the lower value was noticed in the upper horizon (Ap) of pedon (2) at Fayde site (0.15) (Table, 2). Generally, the values of (Fine clay/Coarse clay) ratio of all studied pedons irregularly increased in lower horizons and have a lower value in upper horizons, these values were increased with increasing the depth that refers to the effect of climatic conditions especially precipitation which related with occurring of many soil-forming processes such as weathering, lessivage, leaching, illuviation, and elluviation, these processes occur over a period of time, the period of formation and development of illuviation in soil horizon that was riches with clay as indicated by Alonso et al. (5). In studied pedons (1, 2, and 4) at Semeel, Fayde, and Alton-Kopri sites, the values of (Fine clay/Coarse clay) ratio increased with increasing depth as a result of rainfall that caused transportation, movements, and mechanical migrations for clay particles from upper horizon to the lower horizons when the leaching process occurs. On the other hand, in pedon (3) at Gerderash site, the ratio of (Fine clay/Coarse clay) ranged between (0.33-0.88) the highest value was shown in (Ck) horizon which has a high value, as a result, the movement of clay particles from upper horizons and accumulated in the lower horizon that caused by lessivage process, while in pedon (5) at Wermawa site the ratio of (Fine clay/Coarse clay) ranged between (0.16-0.49) which has the lowest value in the upper horizon that was meant occurring loss process and translocation of fine clay particles from the surface horizons to lower horizons as a result of rainfall. Increasing the ratio of (Fine clay/Coarse clay) led to the dominance of the pedogenic processes such as losses, leaching, gains and in turn soil development Increasing the ratio of (Fine clay/Coarse clay) due to increasing fine clay content as compared with coarse clay as a result of increasing weathering process that causes reducing the size of soil particles particularly of clay fraction, hence can be concluded the value of (Fine clay/Coarse clay) ratio directly proportional with pedogenic processes such as loss and gains, leaching and lessivage. The ratio of (Fine clay/Coarse clay) and its content and distribution is an important criterion for indicating the illuviation horizon, and soil development additionally considers as an indicator of some subsurface diagnostic horizons such as Argillic horizon (18). On the other hand, results of (Fine clay/Coarse clay) ratio showed that the pathway of fine clay similar to the pathway of total clay in study soils which insure the activity of some pedogenic processes and assist in the development process through the movement of clay particles from surface horizons and accumulated it in the subsurface (illuvial) horizons, in turn, these horizons were enrichment with clay content. Movement of clay increased continuously with depth in some study pedons for example in (Bt1) and (Bt2) horizons. Indeed the fine clay particles have the ability of movement more than other soil particles which gives an obvious indicator as we noticed through the displaying the results of clay motion in studied soil pedons, which helps in increasing (Fine clay/Coarse clay) ratio in illuvial horizon comparison with the elluvial horizon, these results agreed with the similar results of Gunal and Ransum (11).

Dominance of pedogenic processes and development of studied soils

Depending on the chemical and physical analyses of studied soils, the following pedogenic processes can be indicated (loss, gain, leaching, illuviation, eluviation, alkalization, humification, lessivage, desalinization, calcification, decomposition, and synthesis). These are considered the major processes for soil formation and represent important criteria in studying soil development, according to these processes, can be differentiated from different soil horizons in studied pedons because these processes occur in vigorously. The results proved that the studied pedons developed, because of the occurrence of many important pedogenic processes that were previously mentioned. On the other hand, soil-forming factors have an important role in developing studied soils, particularly climate which overlaps with other factors. The intensity of these factors specifies the activity of soil-forming processes that were dominant in studied pedon. The ratio of (Fine clay/Coarse clay) was used as a quantitative criterion to specify soil development, depending on the percentage of fine clay and coarse clay and transportation it through soil pedon. The results of (Fine clay/Coarse clay) indicated the development of studied soils as a result of pedogenic processes that were happened and led to the arrangement with re-distributions of soil particles particularly, clay particles because of elluvation and illuviation processes, in B horizon. Mainly, the soil development depends on the amount of precipitation hence; climate factor (precipitation and temperature) was responsible for soil-forming (pedogenic) processes that caused the development of studied soils.

Soic classification: Studied soils were classified depending on the soil properties and climate conditions at family level according to the soil taxonomy that is adopted for use by USDA-NRCS (21) as showed in the table (4).

Table 4. Classification of soils at studied sites

Location	Order	Sub-order	Great group	Sub -group	Family
Duhok (Semeel)	**Vertisols**	**Xererts**	**Calcixererts**	**Typic-Calcixererts**	**Fine clayey, Smectitic, Active, Calcareous, Thermic, Craked**
Mosul (Fayde)	**Aridisols**	**Argids**	**Calciaegids**	**Xeric-Calciaegids**	**Fine clayey, Mixed, Semiactive Calcareous, Thermic**
Erbil (Gerderash)	**Inceptisols**	**Xerepts**	**Calcixerepts**	**Typic-Calcixerepts**	**Fine -silty, Mixed, Active, Calcareous, Thermic**
Kirkuk (AltonKopri)	**Aridisols**	**Argids**	**Calciargids**	**Xeric-Calciargids**	**Fine-silty, Mixed, Active, Calcareuos, Hyper thermic**
Sulaimani (Wermawa)	**Mollisols**	**Xerolls**	**Argixerolls**	**Calcic-Argixerolls**	**Very fine clayey, Mixed,Active Calcareous, Thermic**

CONCLUSIONS

Can be concluded from this investigation the study soils were calcareous and contain a high amount of carbonates, slightly alkaline, non-saline with occurs humification process that was closely related with (A) horizon. The high value of clay content indicated to soil development and the clay content increase towards subsurface horizons of soil pedon as a result of mechanical migration through increasing precipitation. Fine clay/Coarse clay ratio is used as a good criterion to specify soil development. This study showed many important pedogenic processes that happened in soil pedons such as loss, gain, leaching, illuviation, eluviation, alkalization, humification, lessivage, desalinization, calcification, decomposition, synthesis.

REFERENCES

1. Abdullah A. S., A. O. Esmail, and O. O. Ali. 2020. Comparison between chemical and mineralogical properties of oak forest and bare cultivated soils in Iraqi Kurdistan region Iraqi Journal of Agricultural Sciences. 51(Special Issue): 9-20

2. Abdulsada, R. S., and A. I.Hamad. 2020. Evaluation of chemical soil degradation in the Musyab project using of the fuzzy logic in geographic information system. Iraqi Journal of Agricultural Sciences. 51 (Special Issue):53-60

3. Ahmad, N. 1996. Occurrence and Distribution of Vertisols. In: Ahmad N. Mermut, A. (Eds.), Vertisols and Technologies for their Management. Amsterdam, pp; 1–41

4. Al-Jaff B.O., and S. K. Essa. 2020. Effect changesof Mica in rhizosphere. Iraqi Journal of Agricultural Sciences 51 (1):493-999

5. Alonso, P., C. Dorronsor, and J. Egid. 2004. Carbonation in palaeosols formed on terraces of the Torms river basin (Salamanco, Spain). Geoderma, 118, 261- 267.

6. Birkeland, P. W. 1999. Soils and Geomorphology. Oxford University Press,New York,pp; 430.

7. Black, C. A. 1965. Method of soil analysis. Am. Soc. of Agronomy, No.9 Part1 and 2

8. Danielson, R. E., and P. L. Sutherland. 1986. Porosity. In: Methods of Soil Analysis (Ed: Klute A). Part1: Physical and Mineralogical Methods. 2nd Ed. Agronom Monographs, 9ASA-SSA. Madison, WI, pp;.443-461

9. De Jonge, L. W., C. Kjaergaard, and P. Moldrup. 2004. Colloids and colloid-facilitated transport of contaminants in soils: an introduction. Vadose Zone Journal, 3, 321–325

10. Eghbal, M. K., and R. J. Southard. 1993. Micromorphological evidence of polygenesis of three aridisols, western Mojave Desert, California. Soil Sci. Soc. Am. J. 57, 1041–1050

11. Gunal, H., and M. D. Ransom. 2006a. Clay illuviation and calcium carbonate accumulation along a precipitation

12. Jackson, M. L. 1979. Advance soil G, chemical analysis cource-ED.2. Jozefaciu Szatanik-Kloc. .Soil acidity and its effect on plants. Acta Agrophys, 59, 1- 90.

13. Khoshnaw M.R., and A. O. Esmail, 2020. Comparison between organic matter

content of main soil orders in Kurdistan region using two different methods. Iraqi Journal of Agricultural Sciences.51 (Special Issue):1-8

14. Klute, A. 1986. Method of Soil Analysis: Part 1: Physical and Mineralogical Methods, 2nd ed. Agron. Monogr. 9, Madison WI

15. Levine, E. R., and E. J. Ciolkosz. 1983. Soil development in till of various ages in northeastern Pennsylvania. Quat. Res. 19, 85–99

16. Polemio, M. J., and J. D. Rhoads. 1977. Determination Cation exchange capacity a new procedure for calcareous and gypsiferous soils. Soil Soc. Am. Proc. 18:365-368

17. Riebe, C. S., J. W. Kirchner, and R. C. Finkel. 2004. Erosional and climate effects on long-term chemical weathering rates in granitic landscapes spanning diverse climate regimes. Earth and Planetary Science Letters, 224, 547– 562

18. Rowell D L 1996 Soil science methods and application, Welsy, Longman, London

19. Soil Survey Staff. 1998. Keys to Soil Taxonomy: U.S. Department of Agriculture, National Resources Conservation Service

20. Soil Survey Staff. 1999. Key to Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys, 2nd ed. Agriculture Handbook No. 436, SCS- USDA, US Govt. Printing Office, Washington, DC. pp; 869

21. Soil Survey Staff. 2006. Keys to soil taxonomy: Tenth edition, United States, Department of Agriculture natural resources conservation service. Sw. Washington DC

22. Stipp, S. L., M. Hansen, R. Kristensen, M. F. Hochella, L. Bennedsen, K. Dideriksen, T. Balic- Zunic, D. Leonard, and H. J. Mathieu. 2002. Behavior of Fe- oxides relevant to contaminant uptake in the environment. Chemical Geology, 190 (1- 4), 321–337

23. Sutton, S. J., and J. B. Maynard. 1992. Multiple alteration events in the history of a sub- Huronian regolith at Lauzon Bay Ontario Canadian Journal of Earth Science, 29, 432–445.

24. Walkley, A., and I. Black. 1965. Determination of organic matter, In C. A. Black. Method of soil analysis: Part 2. Agronomy, No. 9. Am. Soc. Of Agron, Inc. Madison, Wisconsin, P. 1373-1376. World Reference Base for Soil Resources (WRB). 2006. A framework for international classification, correlation and communication. World soil resources reports 25. 103. FAO, ISRIC, IUSS, Rome, pp;128.

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