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Research article

CHEMICAL PROPERTIES AND CLASSIFICATIONOF SERPENTINITICS SOILS FROM SULAIMANI GOVERNORATE

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ABSTRACT: Serpentinitic soils are wide spread over Penjwin and Mawat area in Kurdistan region of Iraq. Seven pedons were chosen according to the variation in chemical composition of the parent materials that soil developed from. The organic matter content in soils was very low and the highest value was 37.29 g kg^{-1}. The soils generally had alkaline reaction and the pH values ranged from 7.25 to 7.98 which were consistent with carbonate content. The $CaCO_3$ equivalents values ranged from 304.7 to 29.9 g kg^{-1}. The calcic horizons were not present in all the pedons except pedons 4. The presence of ochric epipedon can be identified in Penjwin area and the mollic epipedons can be identified in soils from Mawat area. The pedons of Penjwin area were classified as Incepisols, while the pedons from Mawat area were classified as Mollisols. The dominant clay minerals present in soils from Penjwin area were smectite, chlorite, antigorite and illite while amphibole was present as accessory minerals. However the dominant minerals in soils from Mawat area were smectite, chlorite, and antigorite but calcite and dolomite presence as minor minerals. The soils from Penjwin were classified Tyical Haploxerolls (P1) and Xeric Haplocambids (P2, P3), while the soils from Mawat were classified as Typic Calcixerolls (P4) and Typic Haploxerolls (P5, P6, and P7).
Keywords: Serpentinitic soils, Chemical classification, Sulaimani governorate

INTRODUCTION

The Iraq Zagros Thrust Zone in the north and northeastern Iraq represents a suture zone between the Arabian and Iranian plates to the northeast and the Turkish plate to the north. It occupies an area of about 5000 km^2 along the Turkey-Iraq-Iran border. The Iraqi Zagros Thrust Zone represents a part of the larger Zagros orogen belt which extends about 2000 km from southeastern Turkey through northern Syria and Iraq to western and southern Iran [29].

Five ultramafic rock bodies occur as linear arrays in the Iraqi Zagros Thrust Zone. They are from southwest to northeast as follow, Penjwin ultramafic bodies, Mawat ultramafic bodies, Betwat serpentinized ultramafic bodies, Puza ultramafic bodies and Qalander serpentize ultramafic bodies. The Penjwin igneous complex represents an ophiolite sequence within the larger Zagros belt. It is a northwest-southeast trending elongated body (35 km^2) within the Iraqi territories. While The Mawat igneous complex represents one of ophiolitic sequence within the Iraqi Zagros Thrust Zone. It shows north-south trending longitudinal shape, with 25 km length and 7–12 km width. It covers an area about 15 km^2 with total thickness of 1500 m [28]. Serpentine soils can be produced by ultramafic alone and / or by hydrothermally altered ultramafic minerals in the presence of serpentine minerals. Serpentine soils often pose ecological or environmental risk due to high levels of potentially toxic metals (PTM). The chemistry of serpentinitic soils are broadly characterized by (1) low concentrations of plant nutrients such as N, P, and K, (2) high concentrations of potentially biologically toxic elements including Cr, Ni, Fe, Mn, Co, and Cd, (3) low moisture-holding capacities and (4) low Ca/Mg quotients (Brooks, 1987; Kruckeberg, 1992). Some of these serpentine areas are located in the west and northwest of the country, near the borders of Iraq and Turkey, respectively these ultramafic cover about1, 648,000 km^2 [1]. In Iraq, serpentinitic soils have been studied by [30, 16].

Serpentinitic soils were identified at the family level as having magnesic mineralogy according to Soil Taxonomy (2009). The aim of this investigation is to describe the morphological, physical and chemical properties for the soils developed from serpentines rocks, in order to be able to identify the classification at the family leave of the serpentinitic soil.

MATERIALS AND METHODS

Seven soil pedons were chosen representing two locations of serpentiniyic soils. Penjwin town, which is located 60 km east of Sulaimani city, and Mawat town that is, located 25 km north east of Sulaimani city (Fig 1). A total of 34 soil samples were taken representing different horizons as shown in Table (1). Pedons were morphologicaly described according to the (FBDSS 2002), and the samples were taken from representing horizons of each pedon. Soils samples were air dried and ground by stainless steel to pass through a 2-mm sieve and stored in a polyethylene container prior to analysis.

Table 1: Location and elevation of soil pedons.

location	Profile location	Profile number	**Latitude (North)**	**Longitude (East)**	Elevation
Penjwin	Mla kawa village	P 1	35^{o}35□58□□ N	45^{o} 54□ 59.8□□ E	1306 m
	Mla kawa village	P 2	35^{o}35□ 59.3□□ N	45^{o} 54□ 54.9□□ E	1300 m
	Mla kawa village	P 3	35^{o} 35□ 41.7□□ N	45^{o} 54□ 55.5□□ E	1229 m
Mawat	Betwat village	P 4	39^{o}32□106□□ N	38^{o}53□344 □□ E	1274 m
	Kunjiren village	P 5	39^{o}63□ 001□□ N	38^{o}54□355□□ E	1260 m
	Kura dawia village	P 6	39^{o} 63□009□□ N	38^{o} 54□ 436□□ E	1235 m
	Kura dawia village	P 7	39^{o} 64□011□□ N	38^{o} 54□ 436□□ E	948 m

The particle size was determined according to international pipette method described by (Kilmer and Alexander, 1949). The saturation percentage was determined by gravimetric method**.** The chemical analysis was done according to USDA, Salinity Laboratory Staff (1954). Electrical conductivity of the soil paste extract(ECe) is measured with EC meter to 25° C Model Betz Dearborn-LF 318/Set-Germany
according to Hess (1972).

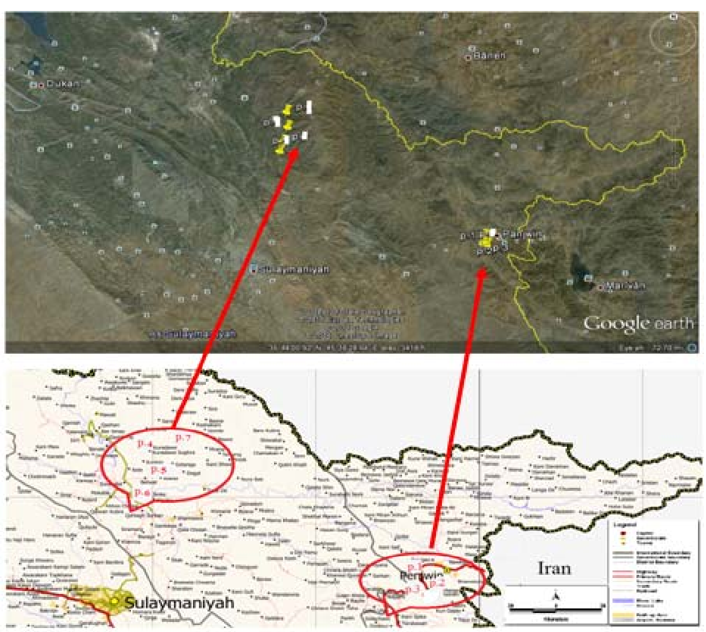

Figure 1: Location of studied areas.

The pH of the soil paste extract was measured with pH-meter Model pH 211- Microprocessor pH Meter-HANNA Com.-Italy, according to [18]. The cation exchangeable capacity (CEC) was determined by using sodium acetate (NaOAc) pH 8.2. The extraction solution was prepared according to the methods of Chapman and Pratt (1930) described by [35]. Organic matter (OM) was determined by wet digestion according to the Walkley and Black as described by Faithfull, (2002). The total calcium carbonate equivalent was determined with 1*M* HCl digestion as described by Richard (1954). While the active calcium carbonate equivalent was determined by the procedure described by [21]. The exchangeable cations were determined by using ammonium acetate (NH_4OAc) pH 7.00 as an extraction solution. Calcium and Mg^{2+} ions were analyzed by titration with the (EDTA) di-sodium salt while Na+ and K+ were analyzed by the flame photometer. All soluble cations and anions were determined by using the procedure that explained in (USDA, Salinity Laboratory Sttaf.1954). Carbonate and bicarbonate anions were determined by titremetric methods using 0.01*M* HCl and phenolphthalein and methyl orange as indicators. The chloride was determined by titration with 0.005 *M* $AgNO_3$ and $K_2Cr_2O_7$ as indicator.
The X-Ray diffraction measurements were done using a Scintag Pad V Diffractometer with CuKα radiation. The instrument used a 2-mm ***divergence slit***, 4-mm incident ***scatter slit,*** 1-mm diffracted beam ***scatter slit***, 0.5-mm ***receiving slit***, an accelerating voltage of 45kV, and a current of 40 mA. Scan parameters used were step sizes of 0.02° and a dwelling time of 2 sec. The semi-quantitative determination of the clay minerals was based on the differences of reflection patterns from K-saturated, Mg-saturated, glycelated heated and air dried samples. The fresh rocks samples were also examined by x-ray diffraction and XRD patterns were recorded over a range of 2 -60 degree 2□. Pre-treatment of the samples, consisted the removal of binding materials such as soluble salts, organic matter and carbonate minerals [23], and free oxids and oxyhydrooxids [26].

RESULTS AND DISCUSSION

The results in Table (2) showed the morphological properties and at the first three sites showed that structure grades were mostly moderate in the surface horizons and weak and structure less in the lower horizons. The granular structure type was the only abundant one in the surface A horizons while sub – angular type or structure less was dominant in the sub surface horizons. The effect of grasses, as dominant native vegetation or cultivated wheat crops, throughout their fibrous shallow roots system was markedly clear on the type of structure in the upper surface horizons. Physical analyses of soils were shown in Table (3). The data generally indicated progressive decreases in clay content with soil depth proportionally with increasing in sand fractions except the (Profile 1) were progressive increases in clay content with soil depth. The texture classes were ranged from sandy loam to clay. These results were in agreement with the results found by Bulmer and Lavkulich, (1994) for ultramafic soils along climatic gradient in southwestern British Columbia. Organic matter (OM) contents were generally greatest in the surface horizon (A) and decreased as soil depth increased. The highest organic matter values was 37.29 g kg^{-1} in Ap horizon of pedon 6 and the lowest value was 0.06 g kg^{-1} in(C) horizon of Pedon 2. The low organic matter content in soil developed from serpentinitic parent material was expected, since these soils were low in vegetative growth. Moreover, the OM content was always less than 40 g kg^{-1}; in comparison with the global OM figures, the soils were very poor. This could be the result of rapid decomposition of the biomass under a prevalent thermic temperature regimes and udic conditions and poor vegetation cover on the serpentine landscape [19, 8, 6, 10]. Cation exchange capacity (CEC) of different soil horizons were fell in the range of 14.62 to 43.88 $cmol_c$ kg^{-1}. Generally, it is well known that soil CEC values positively depend on clay and or organic matter content. However the CEC values were relatively high in all soil horizons of (Pedon 1) which is in consistent with high clay content and the texture classes were silty clay to clay, while the rest of soils were lighter texture. The highest CEC value was found in the A horizons of (Pedon 1) and the values were above 40 $cmol_c$ kg^{-1} which was high.

In spite of low clay content (150 g clay kg^{-1} soil) in P1 A horizon, the CEC value was high, and this may be due to high (21.13 g kg^{-1}) organic matter content. One the other hand, the lowest CEC value was found in soils (Pedon 3) horizon C3 which were low in clay (30.89 g kg^{-1}) and OM content (4.14 g kg^{-1}). Generally, the CEC value was higher at the surface horizons which coincide with high amount of organic matter in spite of low clay content, these results were similar with the results that found by (Lee *et al*., 2001; McGahan and Southard. 2009). The soils generally had alkaline reaction and the pH values ranged from 7.25 to 7.98 which were consistent with carbonate content. The soils developed from serpentine were characterized by moderate content of carbonates and the high value was (304.7 g kg^{-1}) found in the deepest horizons of Pedon 5 horizon C3. These results were in agreement with the results found by (Ghaderian and Baker, 2007; Cheng *et al.*, 2009). The electrical conductivities (Ecs) for the soils ranged from 1.44 dS m^{-1} at A1 horizon in pedon 1 to 0.09 dS m^{-1} at Ap horizon of pedon 4 indicating low salinity level in all soils [32].

Table 2 : Morphological Properties of Soil Pedons

Horizon	Depth	Color	Structure			Consistency	boundary
			Grade	Class	Type		
Pedon 1							
A1	0 -10	2.5Y 6/4	Moderate	Medium	Granular	Friable	Clear, smooth
A12	10 – 28	2.5Y 7/3	Weak	Fine	Granular	Friable	Gradual, smooth
C1	28 – 44	2.5 Y 6/4	Weak	Fine	Angular	Friable	Diffuse , wavy
C2	44 – 70	2.5 Y 7/4	Weak	Medium	Angular	Firm	Gradual, wavy
C3	70 – 82	2.5 Y 6/2	Weak	Medium	Sub-angular	Firm	Gradual , smooth
C4	82 – 95	10YR 6/4	Weak	Fine	Sub-angular	Firm	Gradual, wavy
Pedon 2							
Ap	0 – 20	2.5 Y 4/4	Moderate	Medium	Granular	Hard	Clear, smooth
A12	20 – 35	10YR 4/3	Moderate	Medium	Granular	Loose	Clear , smooth
B	35 – 50	10YR 4/3	Weak	Medium	Sub-angular	Slight hard	Gradual, smooth
C1	50 – 70	10YR 5/4	Weak	Medium	Sub-angular blocky	Hard	Gradual, diffuse
C2	70 – 82	10YR 4/6	Weak	Medium	Blocky	Hard	
Pedon 3							
Ap	0 – 18	2.5 Y 5/3	Moderate	Medium	Granular	Friable	Clear, wavy
A12	18 – 29	2.5 Y 5/4	Weak	Fine	Granular	Friable	Clear ,smooth
C1	29 – 43	2.5Y 5/3	Structure less	Fine	Crumb	Loose	Diffuse, smooth
C2	43 -59	2.5Y 4/4	Structure less	Fine	Crumb	Loose	Clear ,smooth
C3	59- 70+	5Y 5/1	Structure less	Very fine	Crumb	Loose	Diffuse ,wavy
Pedon 4							
Ap	0 – 15	10 YR 5/2	Moderate	Very fine	Granular	Slightly sticky	Clear smooth
A12k	15 – 26	10 YR 5/2	Moderate	Fine	Granular	Slightly sticky	Clear smooth
B1k	26 – 53	10 YR 6/3	Moderate	Fine	Sub-angular	sticky	Clear smooth
C1k	53 – 90	10 YR 5/3	Moderate	Mediukm	Sub-angular	Slightly sticky	Diffuse wavy
C2k	90 – 110	10 YR 5/2	Moderate	Medium	Sub-angular	Slightly sticky	
Pedon5							
Ap	0 -23	10 YR 5/1	Moderate	Medium	Granular	Slightly sticky	Diffuse smooth
A12	23 – 40	10 YR 5/2	Moderate	Fine	Granular	Sticky	Diffuse wavy
B	40 – 65	10 YR 5/2	weak	Very fine	Sub-angular	Sticky	Diffuse wavy
C1	65 – 100+	10 YR 5/2	weak	Fine	Sub-angular	Slightly sticky	Diffuse wavy
Pedon 6							
A1	0 – 20	10YR 6/2	Moderate	Very fine	Granular	Sticky	Clear, smooth
A12	20 – 42	10YR 6/1	Moderate	Fine	Granular	Sticky	Clear, wavy
B	42 – 66	10YR 6/2	Moderate	Fine	Sub angular blocky	Slightly sticky	Clear ,irregular
C	66 – 100	10YR 6/2	Moderate	Fine	Angular blocky	Slightly sticky	Clear ,irregular
Pedon 7							
A1	0 -20	10YR 6/2	Moderate	Very fine	Granular	Sticky	Clear, smooth
A12	20 – 43	7.5YR 7/1	Moderate	Fine	Granular	Sticky	Abrupt, clear
B1	43 – 68	5Y 6/1	Moderate	Fine	Sub angular blocky	Non sticky	Clear, smooth
C1	68 – 90	5Y 7/1	Moderate	Fine	Angular blocky	Non sticky	Clear, smooth
C2	90 -120+	5Y 7/1	Moderate	Medium	Sub angular blocky	Slightly sticky	Clear, smooth

In general, all the soils were characterized by a moderate content of calcium carbonates equivalent ($CaCO_3$) except the soils of pedon 2 which was low in carbonate content. Also, the $CaCO_3$ content was consistently increased with increasing in soil depths. The high amounts of $CaCO_3$ present was found throughout the pedon 5 and they were nearly three times higher than the rest of soils. The highest value was (304.7 g $CaCO_3$ kg $^{-1}$ soil) found in C horizon of pedon 5, but the lowest $CaCO_3$ value was 29.9 g kg $^{-1}$ found in A horizon profile 2. The amounts of $CaCO_3$ present in the soils were above 50 g kg^{-1} and less than 150 g kg^{-1} except soils from pedon 2 were less than 50 g kg^{-1}. So, according to the USDA classification system the soils from all pedons were considered calcareous soils except the soils from profile 2 were slightly calcareous soils (Soil Survey Staff, 2006). It had been noted that some sort of carbonate enrichment in C horizons might be occurred especially in the soils from Mawat area. This might be due to increase in the rainfall average from Penjween to Mawat area. The calcic horizons required thickness > 15 cm and $CaCO_3$ equivalent content >150 g kg $^{-1}$ of soils, which were not present in all the pedons except pedons 5. The results in Table (4) indicate that the $CaCO_3$ content in soils from pedon 5 were more than 150 g kg $^{-1}$..

Table 3: Souble and exchangeable ions in studied soils.

Pedon No.	Horizon	Depth cm	Soluble ions mmol L $^{-1}$						Exchangeable cations C mole$_c$ kg^{-1}			
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
	A1	0-10	2.94	1.10	0.80	0.08	1.00	4.96	10.27	12.55	0.37	0.51
	A2	10-28	1.71	0.46	0.69	0.05	0.48	3.04	10.51	8.18	0.29	0.82
1	C1	28-44	0.93	0.85	0.49	0.04	0.28	1.56	10.74	10.55	0.38	0.72
	C2	44-70	1.70	1.36	1.00	0.07	0.45	3.98	11.89	8.91	0.42	0.92
	C3	70-82	1.13	1.42	0.61	0.03	0.30	2.62	11.72	10.70	0.37	0.92
	C4	82-95	7.01	1.53	0.55	0.38	0.60	12.14	9.85	10.37	0.39	0.97
	Ap	0-20	0.92	0.67	0.76	0.07	0.55	1.58	7.90	6.07	0.30	0.42
	A2	20-35	0.71	0.44	0.50	0.06	0.23	1.28	6.77	5.18	0.23	0.66
2	C1	35-50	1.11	0.92	0.70	0.06	0.50	1.68	3.36	7.97	0.57	0.46
	C2	50-70	0.90	0.67	0.35	0.02	0.38	1.58	5.97	7.10	0.48	0.26
	C3	70-82	0.73	0.74	0.50	0.03	0.33	1.16	6.97	6.90	0.67	0.41
	Ap	0-18	1.12	0.66	1.01	0.09	0.78	2.78	4.17	5.18	0.54	0.41
	A2	18-29	0.80	0.69	0.97	0.06	0.63	1.86	3.98	4.18	0.46	0.31
3	C1	29-43	0.98	0.74	0.97	0.07	0.88	2.18	3.97	3.58	0.86	0.26
	C2	43-59	1.99	1.18	0.95	0.08	0.38	2.62	2.15	2.57	0.99	0.31
	C3	59-70	0.70	0.58	0.48	0.04	0.25	2.02	3.08	3.18	0.32	0.26
	Ap	0-15	3.01	2.72	0.32	0.76	1.99	6.42	10.00	15.65	2.79	1.00
4	A1	15-26	1.60	1.31	0.28	0.25	0.96	2.76	10.60	12.90	1.36	0.48
	B1	26-53	1.45	0.83	0.28	0.28	0.83	2.42	10.00	12.25	1.70	0.44
	C1	53-69	1.14	1.24	0.53	0.21	1.65	2.55	10.40	14.70	1.72	0.86
	C2	69-90	1.25	1.48	0.22	0.30	0.94	2.68	10.00	15.10	1.30	0.52
	Ap	0-23	2.24	1.58	0.47	1.44	1.14	5.46	16.20	17.40	1.85	1.48
5	A	23-40	1.70	0.79	0.46	0.12	1.08	3.14	14.70	14.66	1.29	0.52
	B	40-65	1.93	1.05	0.47	0.14	1.04	2.94	16.10	15.36	1.55	0.62
	C1	65-100	1.70	1.28	0.34	0.18	1.06	2.86	15.80	14.20	1.49	0.53
	A1	0-20	1.93	3.50	0.46	0.44	1.93	5.55	17.80	16.50	1.93	0.81
6	A2	20-42	2.12	2.24	0.42	0.16	1.29	5.35	16.40	12.96	1.82	0.35
	B	42-66	1.21	1.62	0.39	0.09	0.91	3.56	15.40	16.96	1.20	0.34
	C	66-100	1.26	1.49	0.40	0.09	1.78	2.25	14.30	16.60	1.30	0.38
	A1	0-20	1.82	0.99	0.22	0.44	0.99	3.64	16.20	16.06	2.35	0.86
	A2	20-43	0.78	0.79	0.13	0.07	0.80	1.66	15.00	14.06	11.92	0.28
7	B1	43-68	1.80	1.58	0.14	0.09	0.96	2.00	14.70	14.10	1.91	0.27
	C1	68-90	0.75	0.66	0.15	0.07	0.92	1.40	11.90	15.66	1.91	0.24
	C2	90-120	0.89	0.86	0.12	0.11	0.90	1.68	12.20	15.16	1.93	0.28

This may be due to either contaminated carbonate rich material or the soil had been developed from parent material rich in carbonates in addition to serpentinite rocks. It is well known that the soils developed from serpentinite rocks would be low in $CaCO_3$ (Deer *et al*., 1997; O'Hanley, 1996). On the other hand, active calcium carbonate (A-$CaCO_3$) ranged between 86.5 g kg^{-1} at C horizon in pedon 5 to 10.0 g kg^{-1} at (AP, A12) in pedon 2 and 4 respectively. This difference may have been resulted from the differences in parent material and different leaching processes.

The percentage of base saturation (PBS) of soils in each horizon was ranged from 24.06 at C4 in pedon 3 to 99.73 at C4 horizon in pedon 7. The PBS of the diagnostic horizon in pedon 2, and 3 were generally less than 350 g kg^{-1}, while in pedons 1, 4, 5, 6, and 7 were always significantly more than 350 g kg^{-1} ,therefore the pedons 1, 2, and 3 were classified as Inceptisols, while pedons 4, 5, 6, and 7 were classed as Mollisols according to the requirement of PBS and horizon defined in soil Taxonomy (Soil Survey Staff, 2006). The classification for all soils through the subgroup level in Soil Taxonomy is shown in Table (2) [5, 14, 17]. Table (4) showed the Ca/Mg ratio of soils and the total Ca/Mg ratio were ranged from 2.35 to 0.51 for soils, these ratio were less than one for soils in pedon 3 and 6, while in other pedons were more than one. The total Mg contents were much higher than Ca in soils [10, 32]. This may reflect the chemical composition of the parent materials which were rich in ferromagnesian minerals such as olivine, pyroxene and amphiboles [2, 28], in addition to other minerals (dioctahedral clay minerals). Total or extractable Ca/Mg has been a sometimes useful indicator of serpentinite- derived soils. An NH_4Oac-extactable Ca/Mg of 0.7 or greater is generally desired for agricultureral crop production [7, 3]. The distribution of different soluble and exchangeable cations and anions were shown in Table (3). The results indicated that Ca^{2+} and Mg^{2+} were the main cations present in soil solution as soluble and exchangeable. The values of soluble Ca^{2+} ranged from 7.01 to 0.43 m mole L^{-1}, while soluble Mg^{2+} cations ranged from 3.50 to o.44 mmol L^{-1}. On the other hand, Na^+ and K^+ were lower than 1.0 m mole L^{-1}. These values were expected since these soils had been developed from rocks, high in Mg and low in Na^+ and K^+.

The exchangeable Ca and Mg were ranged from 17.80 to 1.67 c mole kg^{-1} and 17.40-1.37 c mole kg^{-1} respectively and the exchangeable Ca and Mg were higher at the surface horizons. But the values of exchangeable Ca and Mg were much higher in soils from Mawat than Penjwin area. This may be due to the variation in parent material and the variation in climatic factors especially precipitation which was higher in Penjwin area than in Mawat area. So, the leaching of soluble cations was much higher in Penjwin area than Mawat area. The results in Table (3) indicated that the main anion present was bicarbonate and the values were ranged from 12.14 to 0.92 mmol L^{-1}. But the value of Cl^{-1} ion was very low and the values were ranged from 1.99 to 0.20 mmol L^{-1}, and the highest values were found in the surface horizons. These values were conceded with pH and Ec values. The soil from Mawat area had showed some accumulation (enough) organic carbon to acquire mollic epipedons, while the soils from Penjwin area had less organic carbon than requirements for mollic epipedons. The organic carbon contents of the surface horizons of pedon 1 to 3 were less than 6.0 mg kg^{-1} to the required depth for mollic epipedons [34]. Requirements for mollic epipedons seem to be present in soils represented by pedons 4, 5, 6, and 7. The calcic horizon is 15 cm or more thick and calcium and magnesium carbonate equivelant has accumulated. It contents 150 mg kg^{-1} $CaCO_3$ equivalent and its $CaCO_3$ equivalent is 5% or more high than the C horizons. Calcic subsurface horizon was only present in pedon 4 and it was more likely that this soil fit best in Typic Calcixerolls, while the morphological and chemical properties Table (5) showed that pedons 5, 6, and 7 fit best in Typic Haploxerolls. The presence of ochric epipedon can be identified due to little organic carbon content and had high colour value than chroma. The soils in pedon 1 can be classified Inceptisols to Typic Haploxerepts, while the rest of pedon 2 and 3 can be fit in Xeric Haplocambids. The results of X-ray diffraction of clay minerals indicated that the main abundant primary clay minerals lithogenic within serpentinatic soils were chlorite and antigorite minerals. Illite and smectite were not present in the rock sample so these were pedoginecally formed. Smectite, often the most abundant constituent of the clay fraction in serpentinatic soils [13], and the pedogenic formation of smectite had been lilied to topographic position [25]. Smectite may be a weathering product of serpentine [13].

On the other hand, smectite may be formed from chlorite, and it had been found that the ultimate formation of smectite through the alteration of chlorite to vermiculite [24]. Since vermiculate could not be detected in these soils, the formation of smectite from chlorite could not be possible. Smectite, chlorite and serpentine were found within poorly drained soil but found only serpentine and chlorite in well drained upland soils [5]. So, further investigation will be needed to confirm the pedogenesis of these minerals. Semi-quantitative clay minerals analysis presented in Table (6). The clay fraction from Mawat area contains talc in addition to other clay minerals, which was not detected in soil samples from Penjwin area. It had been reported that the talc minerals was present in serpintinite rocks [28]. But smectite, antigorite and chlorite were the dominant clay minerals present in these soils. Illite mineral was present in a very minor phase, but illite was present as one of the dominant clay mineral in soils from Penjwin area. The variation may be due to higher rainfall in Penjwin area which leads to higher weathering and transformation of primary minerals present in serpentinitic soils to illite and smectite.

Table 4 : **Some physical and chemical properties of studied soils.**

Pedon No.	Horizon	Depth cm	PSD g kg^{-1}			pH	Ece dS m^{-1} at 25° C	CEC Cmole$_c$ kg^{-1}	O. M	CaCO$_3$		PBS (%)	Ca/ Mg
			Sand	Silt	Clay				g kg^{-1}	Total	Active		
1	A1	0-10	493.2	388.8	118.0	7.46	0.44	30.94	29.65	39.9	20.0	76.60	1.04
	A2	10-28	324.7	515.8	159.5	7.70	0.34	24.10	2.05	35.8	15.0	82.16	1.03
	C1	28-44	322.2	545.4	132.4	7.58	0.28	28.46	2.92	36.9	25.0	68.67	1.05
	C2	44-70	460.9	428.9	110.2	7.53	0.37	26.48	0.82	37.7	35.0	83.61	1.09
	C3	70-82	639.7	327.5	32.8	7.50	0.22	25.16	0.38	49.4	25.0	94.23	1.19
	C4	82-95	499.3	380.8	119.9	7.61	0.13	26.08	0.35	54.1	16.0	82.74	1.12
2	AP	0-20	470.0	380.0	150.0	7.90	0.68	43.88	21.13	37.7	10.0	33.48	1.06
	A2	20-35	137.8	401.2	461.0	7.81	0.45	40.92	3.96	72.4	20.0	31.38	1.00
	C1	35-50	120.6	392.4	487.0	7.70	0.25	41.10	3.44	78.7	20.0	30.07	0.95
	C2	50-70	91.7	376.3	532.0	7.87	0.58	42.69	2.86	77.7	25.0	32.35	0.95
	C3	70-82	84.4	360.3	555.3	7.78	0.37	43.08	0.70	76.5	20.0	34.70	1.05
3	AP	0-18	467.7	385.6	146.7	7.94	0.49	30.95	13.25	62.1	15.0	33.28	0.90
	A2	18-29	559.4	315.6	125.0	7.93	0.37	28.58	6.07	69.4	35.0	31.24	0.78
	C1	29-43	647.0	255.5	97.5	7.95	0.52	27.39	8.64	73.1	20.0	31.65	0.75
	C2	43-59	775.3	169.3	55.4	7.74	0.59	25.02	5.87	71.2	30.0	24.06	0.69
	C3	59-70	845.3	123.8	30.8	7.80	0.33	22.62	4.14	74.3	20.0	30.24	0.70
4	Apk	0-15	468.0	299.5	232.5	7.25	0.52	38.81	20.49	183.2	74.0	77.11	0.80
	A1k	15-26	733.9	136.3	129.8	7.42	0.40	34.98	14.24	265.8	75.0	78.16	0.90
	B1k	26-53	786.5	103.6	109.9	7.63	0.30	32.15	10.92	269.8	77.5	82.08	0.78
	C1k	53-69	554.4	207.1	238.5	7.42	0.28	34.21	16.34	287.2	86.5	84.24	0.68
	C2k	69-90	762.7	127.9	109.4	7.83	0.35	32.18	12.26	304.7	76.5	83.65	0.51
5	Ap	0-23	584.3	260.8	154.9	7.66	0.50	37.37	37.29	92.4	83.0	98.82	1.18
	A	23-40	615.6	253.7	130.7	7.94	0.31	32.12	16.28	98.1	81.0	97.04	1.26
	B	40-65	635.2	214.3	150.5	7.87	0.40	37.01	21.25	102.7	83.5	90.86	1.32
	C1	65-100	673.1	244.1	82.8	7.85	0.45	33.81	18.91	125.9	75.0	94.70	1.34
6	A1	0-20	729.9	161.6	108.5	7.93	0.52	38.90	21.59	93.2	79.5	95.22	1.38
	A2	20-42	586.7	329.7	83.6	7.75	0.51	32.71	15.17	99.6	80.0	96.39	1.33
	B	42-66	661.8	210.6	127.6	7.92	0.40	34.62	15.06	107.9	78	97.92	1.14
	C	66-100	689.5	247.1	63.4	7.98	0.39	32.81	11.32	109.9	78.5	99.30	0.93
7	A1	0-20	395.9	452.8	151.3	7.70	0.39	37.84	28.02	102.9	77.5	91.09	0.91
	A2	20-43	661.2	248.5	90.29	7.91	0.23	32.60	14.88	105.2	80.0	95.89	1.42
	B1	43-68	633.2	277.2	89.6	7.35	0.30	31.40	11.85	108.8	82.5	98.66	1.50
	C1	68-90	722.9	217.3	59.8	7.58	0.20	29.79	04.26	117.5	80.5	99.73	1.54
	C2	90-120	701.3	236.9	61.8	7.70	0.22	30.40	04.61	118.1	80.0	97.27	1.50

Table 5: Classification of investigated studied soils.

Pedon No.	Location	Order	Sub order	Great-group	Sub Great-group
1	Mlakawa/Penjwin	Inceptisols	xerepts	Haploxererts	Typic Haploxerepts
2	Mlakawa/Penjwin	Inceptisols	cambids	Haplocambids	Xeric Haplocambids
3	Mlakawa/Penjwin	Inceptisols	cambids	Haplocambids	Xeric Haplocambids
4	Mlakawa/Penjwin	Inceptisols	cambids	Haplocambids	Xeric Haplocambids
5	Betwat / Mawat	Mollisols	Xerolls	Calcixerolls	Typic Calcixerolls
6	Kunjiren / Mawat	Mollisols	Xerolls	Haploxerolls	Typic Haploxerolls
7	Kura Dawia1/Mawat	Mollisols	Xerolls	Haploxerolls	Typic Haploxerolls
8	Kura Dawia2/Mawat	Mollisols	Xerolls	Haploxerolls	Typic Haploxerolls

Table 6: Semi-quantitative distribution minerals clay fractions from soils and rocks samples collected from Penjwin and Mawat area.

Pedon and rock No.	Horizon	Mineral type								
		Antigorite	Smectite	Chlorite	Illite	Talc	Amphibol	Quartz	Calcite	Dolomite
P 3	Ap	+ + +	+ + +	+ + +	+ +	-	+	+ +	-	-
	A2	+ + +	+ + +	+ + +	+ +	-	+	+ +	-	-
	C1	+ + +	+ + +	+ + +	+ +	-	+	+ +	-	-
	C2	+ + +	+ + +	+ + +	+ +	-	+	+ +	-	-
	C3	+ + +	+ + +	+ + +	+ +	-	+	+ +	-	-
P 4	Ap	+ + +	+ + +	+ + +	+	+ +	+	+	-	-
	A1	+ + +	+ + +	+ + +	+	+ +	+	+	-	-
	B1	+ + +	+ + +	+ + +	+	+ +	+	+	-	-
	C1	+ + +	+ + +	+ + +	+	+ +	+	+	-	-
	C2	+ + +	+ + +	+ + +	+	+ +	+	+	-	-
Rock 1		+ + +	-	+ + +	-	-	I	-	-	-
Rock 2		+ + +	-	+ + +	-	-	I	-	I	I

Where: ++++ = Dominant +++ = Major ++ = Minor + = Trace

The dominate clay minerals present in serpentinitic soils from Penjwin area were smectite, chlorite, antigorite and illite while amphiboles and quartz were present as accessory minerals, however the dominant minerals in soils from Mawat area were smectite, chlorite and antigorite. Quartz was also present in Mawat area but as a minor phase and its content was less than soils from Penjwin area. The rock samples from Mawat area showed presences of calcite and dolomite as a minor mineral. This conceded with the highest carbonate presence in soils from Mawat area.

To distinguish families of minerals soils within a subgroup, the following criteria were used, and they were particle size classes, mineralogical, temperature regime, reactivity and reaction classes. The results of particle size showed in Table (4) indicated that are course loamy texture class. Soil temperature classes defined in terms of mean annual temperature. The mean annual temperature was between12 to 22 ^{o}C and the difference was more than 15^{o} C between mean summer and winter temperatures so, the soil temperature regime or class was Thermic. The reactivates can be determined by dividing percent CEC by percent clays and the results indicated that the reactivity values were more than 0.6, so the soils had super active. Therefore the soils can be classified as: coarse loamy, mixed, Thermic Super active, Calcareous Typic Haploxerepts.

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