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Comparison of two different ophiolite districts in terms of some soil physical properties of grounds

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Abstract

In this study, some physical characteristics of the soils formed on the metamorphic sole and the mantle section of the ophiolitic sequence which is represented by ultramafic cumulates and tectonites located in Karacasu district in Kahramanmaraş and formed on the crustal rocks which are located around Göksun-Elbistan towns to the north of Kahramanmaraş, were investigated. In order to correlate the soil properties with the bedrocks from the different parts of the ophiolite, rock samples were collected from the same locations with 18 surface soil samples. Field capacity, permanent wilting point, liquid limit, plastic limit, coefficient of linear extensibility and volumetric shrinkage tests were performed on the soil samples. The crustal section is represented by the three different rock groups such as: cumulate gabbro (amphibole gabbro, olivine gabbro and gabbro), isotropic gabbro (gabbro) and sheeted dike complex (diabase). According to independent "t test" results; the physical properties of two fields were different from each other, except for the linear extension coefficient, ($P<0.001$). Statistically significant relationships were determined among the measured variables, organic matter content, and soil texture. This is attributed to the fact that the ophiolites in the Karacasu area are more altered than the ophiolites in the Göksun-Elbistan area, and this difference in the alteration affects the soil properties over the mineralogical composition.

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Introduction

Ophiolitic units are described as the remnants of the oceanic lithosphere formed on the continental margin of the ocean or on the intra-oceanic subduction zone (Miyashiro, 1975; Pearce et al., 1981; Gass, 1990). The ophiolitic bodies in the Alpine-Himalayan belt are very different in terms of their tectonic settings and all of the ophiolites in Turkey present typical characteristics of the ophiolites formed on the intra-oceanic subduction zone (Robertson, 2002; Rızaoğlu et al., 2006; Parlak et al., 2009).

The Neotethyan ophiolites in Turkey are located in five east-west trending belts. These are namely, Tauride ophiolite belt, Middle Anatolian ophiolite belt, Pontide ophiolite belt, Southeastern Anatolian ophiolite belt and Peri-Arabian ophiolite belt. The ophiolitic rocks in the south of Kahramanmaraş are located within the

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Peri-Arabian ophiolite belt while the ophiolitic units in the north (Göksun ophiolite) are located in the Southeastern Anatolian Ophiolite belt. The mantle section rocks representing the lower part of the ophiolite are located in the south, where as the rock groups representing the crustal part are cropped out in the north. In terms of rock classification, tectonitic rocks are represented by serpentinize harzburgite, dunite and serpentinite. Because of the transformations to talc and serpentine group minerals, the pyroxene and olivine group minerals are observed as lost their original properties. In addition, sub-ophiolitic metamorphic rocks with inverted metamorphic zone as a very thin slice, which are related to the thrusting of the old oceanic lithosphere on the continent are seen at the base of the tectonitic rocks, and these rocks are dominantly represented by amphibolite and amphibole schists. In mantle section and the metamorphic sole rocks just below it, the alteration level is significantly different from the crustal rocks observed in the north, and this provides a easy recognition of differences in soil formation too. In the north, the ophiolitic rocks around Göksun-Elbistan are starting with cumulate gabbro, and these rocks are represented by amphibole gabbro, olivine gabbro and gabbro. The isotropic gabbros just above them are seen in a narrow field and attracting attention with their light color. Isotropic gabbros are represented by gabbro. On the upper part, the sheeted dyke complex, which is the rocks of the uppermost section of the ophiolitic sequence in the region, and diabasic rocks are identified as rock type of this section (Parlak, 2009, 2013).

There is a close relationship between the soil properties and the origin of the parent material. Soil formation in dry and semi-arid regions, where climate and vegetation cover is inadequate, is almost controlled by the parent material. The ophiolitic units are widely seen in Kahramanmaraş region and have different geochemical and petrographic characteristics (Kısakürek, 1988; Tanirli and Rizaoglu, 2016). The influence levels of soils formed on these units from parent material carries great importance. The soils formed on the ophiolite are typically shallow, gravelly, poorly structured, with high porosity hydraulic conductivity values and low water holding capacity, generally poorly suited to plant breeding (Proctor, 1975). Baillie et al. (2000) have found that morphologically similar reddish colored, clay-textured, scattering structured soils are formed on lithologically heterogeneous ophiolite parent materials.

In this study, the differences between some physical properties of soils formed on ophiolites with different geochemical and petrographic characteristics in Elbistan-Göksun and Karacasu areas were investigated and the relationships between these differences and their levels influenced by the main materials were determined.

Material and Methods

Location of study area and general characteristics

Kahramanmaraş city is geographically composed of mountains extending from west to east with plains and valleys between these mountains. The city is located in the transection zone of Mediterranean climate and continental climate. The Mediterranean climate reaches up to the inner parts through the valleys of the Ceyhan River.

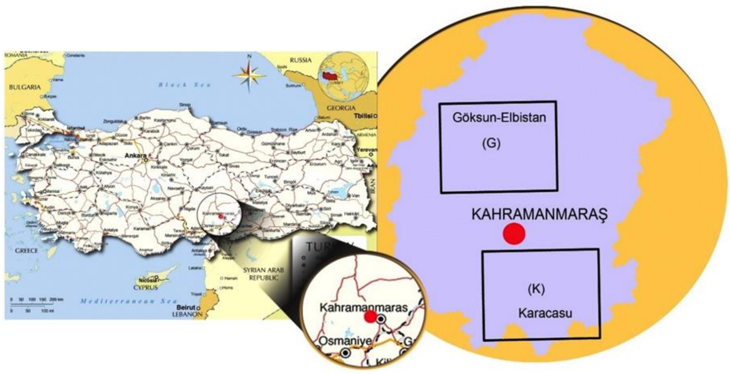

Figure 1. Location map of the study area

In the study area, mainly terrestrial climate is dominate in the north (Göksun-Elbistan) and Mediterranean climate in the South (Karacasu). According to Kahramanmaraş Meteorology Station, the total annual precipitation is 729 mm and most of the precipitation falls in winter and early spring (81%). The average annual temperature is 16.5°C, with the highest temperature in August (28 °C) and the lowest in January (4.5 °C) (TSMS, 2016). Location map of study area is given in Figure 1.

Soil sampling procedure

Disturbed soil samples were collected from each study area of 18 different points according to layered random sampling technique. When applying this method, geological differences and vegetation changes were considered. Surface soil samples were taken from 0 to15 cm depth. Coordinates of sampling points are given in Table 1. Geological and soil maps of two different locations are given in Figure 2 and Figure 3, respectively. Sampling points were shown on these maps.

Table 1. Coordinate of sampling points

No	Coordinate UTM		No	Coordinate UTM	
	East	North		East	North
G1	4212464	286303	K1	4154792	322768
G2	4212478	286300	K2	4153794	320484
G3	4217099	302196	K3	4154087	321675
G4	4220387	311866	K4	4152723	321415
G5	4221456	312444	K5	4151384	320845
G6	4221961	313142	K6	4149392	320411
G7	4222424	313221	K7	4147782	320404
G8	4227038	305804	K8	4152442	324618
G9	4229378	310415	K9	4156180	332508
G10	4223137	324724	K10	4152798	331174
G11	4195888	320864	K11	4151383	335523
G12	4197050	321670	K12	4152667	336893
G13	4199950	327037	K13	4155447	342000
G14	4200000	327603	K14	4156903	345900
G15	4202089	330123	K15	4135919	323018
G16	4202805	320038	K16	4134217	320721
G17	4204583	320717	K17	4130904	319008
G18	4205449	323168	K18	4130928	314491

G: Göksun-Elbistan district, K: Karacasu district

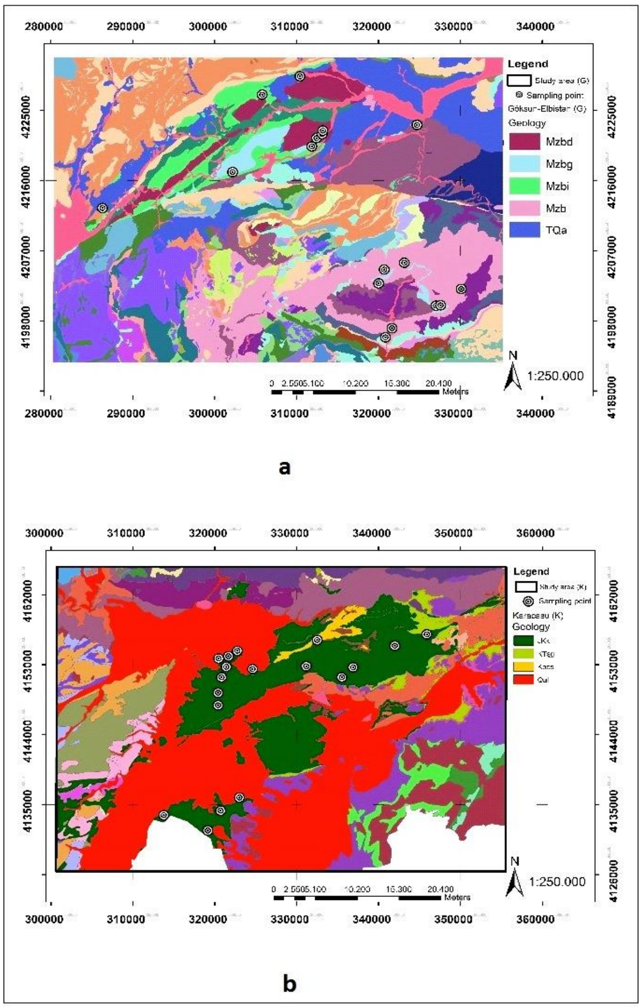

Figure 2. Geologic formation maps of study areas (a: Göksun- Elbistan district (G) and b: Karacasu district (K)), Mzbg: Layered Gabro, Mzbd: Sheeted dike complex, MzbI: Isotropic gabbro, TQa: Ahmetcik Formation, Mzb: Berit Meta Ophiolite, JKk: Kacali complex, KTşg: Germav Formation, Kbes: Sarica Marl Member, Qal: Alluvium

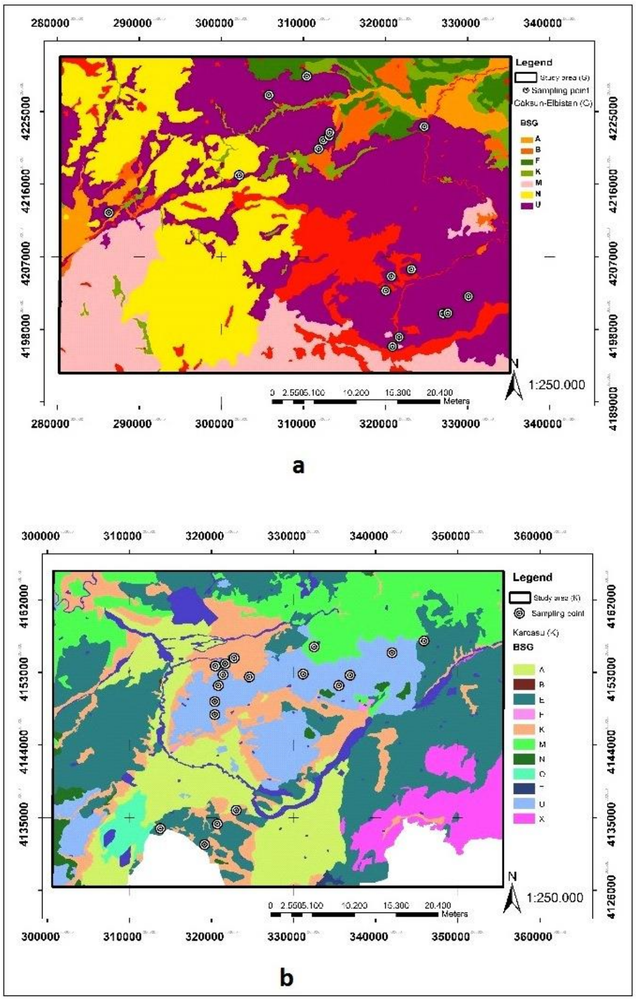

Figure 3. Soil maps of study areas (a: Göksun- Elbistan district (G) and b: Karacasu district (K)), A: Alluvial soils, B: Brownish soils, F: Reddish Brown soils, K: Colluvial soils, M: Brownish Forest soils, N: U: Lime less Brown soil, E: Terra Rosa soils, O: Organic soils, T: Reddish Mediterranean soils, X: Basaltic soils

Determination of soil properties

Some soil characteristics were determined as follows; particle size distribution by Bouyoucous' hydrometer method (Demiralay, 1993), soil organic matter content by wet digestion method (Kacar, 1994), coefficient of linear extensibility (COLE) by mud stick method (Schafer and Singer, 1976), volumetric shrinkage (SV) by standard procedure of ASTM (ASTM, 1974; Ferry and Olsen, 1975). After saturating soil samples with tap water for 24 hours, soil water content at the field capacity (FC) was measured equilibrating soil moisture for 24 hours at 33 kPa on a ceramic plate, and the permanent wilting point (PWP) was measured equilibrating soil moisture for 96 hours at 1500 kPa on a pressure plate apparatus (Gülser and Candemir, 2014). To determine liquid limit (LL), about 120 g of the soil sample passing 425-micron sieve and LL was determined according to Zerdi et al., (2016). To determine plastic limit (PL), 120 g of dry soil passed through the 425 micron IS sieve and PL was determined according to Zerdi et al. (2016).

Mineralogical evaluations in rocks

Before petrographic determinations were made on the rocks collected from the study area, a thin section of each sample was prepared. During this process, the chips obtained from the rocks were sanded and glued on a 22x48x1.5 mm lamella with Canadian balsam and the glued material was abraded and polished to the optimum thickness of 30 microns. It was then covered with thin glass laminates for easy viewing and clear images. The produced thin sections were examined under Nikon 50i pol Model polarizing microscope by means of textural and mineralogical characteristics.

Statistical evaluations

General evaluations of obtained data set were implemented on descriptive statistics. In order to compare two study areas in terms of measured variables, independent t test was used. Relations between soil characteristics were revealed by correlation tests. All statistical evaluations were made in the SPSS package (Efe et al., 2000).

Results and Discussion

Findings about ophiolit rocks

In the present study, the ophiolitic rock samples derived from the different levels of the sub-units showed far differences each other. The ophiolitic samples collected from Elbistan region belong to Göksun ophiolite and represent the crustal section of an ideal ophiolitic suite, wheras the ophiolitic samples from Karacasu region showed the typical characteristics of the mantle section.

The selected rock units in the Göksun ophiolite start at the bottom with the gabbroic cumulates. The mafic cumulate rocks are represented by amphibole gabbro, olivine gabbro and gabbro. The amphibole gabbro displays granular to poikilitic textures: it comprises amphibole (hornblende), plagioclase and Fe-Ti oxide minerals (Figure 4a). The olivine gabbro displays granular to poikilitic textures: it comprises olivine, plagioclase, clinopyroxene, orthopyroxene, chromite and Fe-Ti oxide minerals. All the mafic cumulates show poikilitic texture. Serpentine, chlorite, talc, epidote, and amphibole are secondary phases (Figure 4b). The gabbro shows granular to poikilitic textures comprises Plagioclace, clinopyroxene and Fe-Ti oxide minerals. The minor amount of epidote and chlorite represent the secondary mineral formation (Figure 4c). The gabbroic cumulate rocks directly pass into the isotropic gabbros which is dominated by gabbros. Gabbros show a non-cumulus granular to poikilitic texture and characterized by primary plagioclase, clinopyroxene, orthopyroxene and opaque (Fe-Ti oxide) minerals (Figure 4d). The investigated section of the Göksun ophiolite reaches to the sheeted dikes at the top. The dykes exhibit intergranular, doleritic and microgranular textures. The main mineral phases are plagioclase, pyroxene, amphibole, quartz and magnetite. The sheeted dyke rocks are often associated with secondary calcite, amphibole, chlorite and epidote (Figure 4e). On the other hand, the rock units from Karacasu region start at the bottom with thin sheet of metamorphic sole unit tectonically underlies the mantle tectonites to the South-southeast of Kahramanmaraş. The metamorphic sole is represented by amphibolites and plagioclase- amphibole schist. The plagioclase-amphibole schists display nematoblastic textures and comprise amphibole, epidote, plagioclase and secondary chlorite and magnetite (Figure 4f). The amphibolites exhibit granoblastic texture and comprise coarse-grained hornblendes as the main mineral phase (Figure 4g). The tectonitic section of the mantle is characterized by serpentinized peridotitic rocks such as harzburgite, dunite and serpentinite. Harzburgitic and dunitic rocks show granular to mesh texture and harzburgites are mainly composed of olivine and orthopyroxene, dunitic rocks are dominated by olivine (Figure 4h and 4i). Serpentinites display mesh texture (Figure 4j). All the ultramafic rocks include chromite as the opaque mineral.

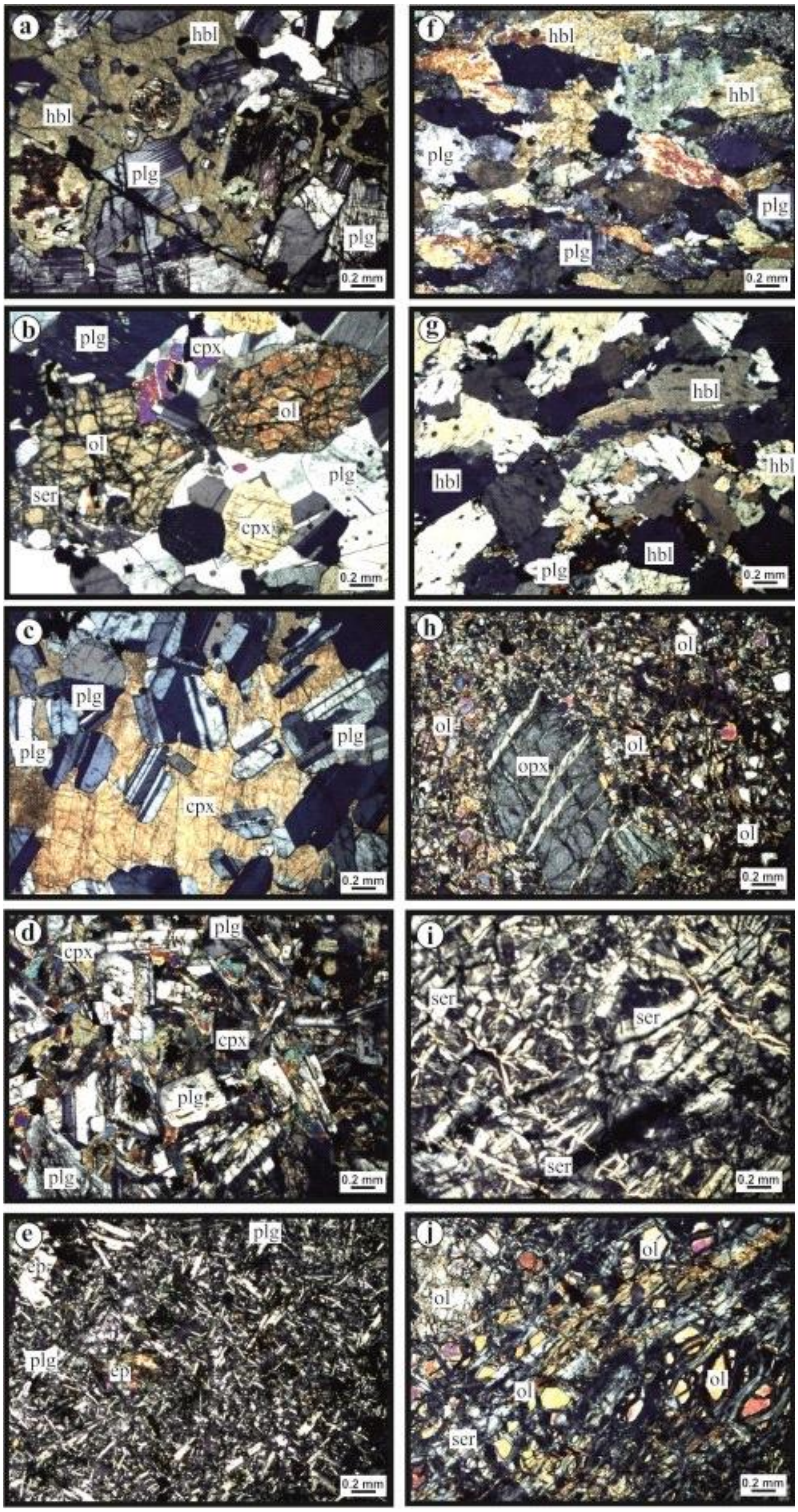

Figure 4. Electron microscopic images. a) Poikilitic texture in amphibole gabbro from cumulate gabbroic section b) Poikilitic texture in olivine gabbro from cumulate gabbroic section c) Poikilitic texture in gabbro from cumulate gabbro section d) Granular texture from isotropic gabbro e) Intergranular texture in diabase from sheeted dike section f) Nematoblastic texture in plagioclase-amphibole schist from metamorphic sole g) Granoblastic texture in amphibolite from metamorphic sole h) Mesh and Granular texture in serpentinized harzburgite from tectonite unit i) Mesh texture in serpentinite from tectonite unit j) Granular and Mesh texture in dunite from tectonite unit. Abbreviations: *ol* olivine, *kf* k-feldspar, *opx* orthopyroxene, *cpx* clinopyroxene, *ser*: serpentine group minerals, *plg* plagioclase, *q:* quartz, *hbl* hornblende, *ep* epidote, *chl*: chlorite, *cal*: calcite, *mag*: magnetite.

Findings about soils

Descriptive statistics of soils are given in Table 2. As shown in this table, LL values of Göksun-Elbistan soils were found between 17.33-54.96% and that of soils of Karacasu location between 27.54-57.54%. In the same order, for two locations, mean PL values were measured as 24.98 and 37.59%. On the Göksun-Elbistan soils, mean while COLE was determined as 0.055 this value was determined as 0.062 on the Karacasu soils. Mean SV value of Göksun-Elbistan district was measured as 5.21% and the same variable was measured as 14.30 for Karacasu soils. When examining this table in terms of soil moisture constants, it was seen that FC value of Göksun Elbistan soils were between 7.50-29.33% and that of soils of Karacasu location were between 11.82-38.57%. Minimum and maximum PWP values of Göksun-Elbistan soils were measured as 4.19-18.31%, and these values were determined as 7.91-30.13% for Karacasu soils (Table 2).

Table 2. Descriptive statistics

Location	Statistical term	Variables					
		LL	PL	COLE	SV	FC	PWP
Göksun-Elbistan location	Mean	30.94	24.98	0.055	5.21	17.58	9.79
	Standart error	8.15	7.32	0.053	5.42	5.92	3.84
	Median	28.69	24.22	0.035	3.30	17.47	9.34
	Minimum	17.33	7.69	0.008	0.01	7.50	4.19
	Maximum	54.96	45.62	0.195	20.80	29.33	18.31
	Kurtosis	2.054	1.85	0.286	1.70	-0.43	-0.51
	Skewness	1.19	0.30	1.087	1.59	0.25	0.556
	Harmonic mean	29.12	22.19	0.019	4.17	15.47	8.36
	Geometric mean	29.99	23.77	0.032	6.11	16.55	9.06
Karacasu location	Mean	45.26	37.59	0.062	14.30	28.49	20.62
	Standart error	10.09	7.79	0.035	6.60	8.04	6.78
	Median	48.91	40.48	0.067	16.0	31.19	21.29
	Minimum	27.54	24.44	0.011	3.30	11.82	7.91
	Maximum	57.54	53.78	0.132	24.6	38.57	30.13
	Kurtosis	-1.27	-0.71	-1.090	-1.10	-0.55	-1.11
	Skewness	-0.543	-0.05	0.092	-0.161	-0.897	-0.44
	Harmonic mean	42.71	35.93	0.036	10.19	25.30	17.77
	Geometric mean	44.04	36.77	0.050	12.40	27.06	19.30

LL: Liquid limit, PL: Plastic limit; COLE: Coefficient of linear extensibility, SV: Volimetric shrinkage, FC: Field capacity, PWP: Permanent wilting point

The comparison of two locations by independend t test was given in Table 3. Soils of both sides were statistically different from each other in term of measured variables, except COLE. These differences were significant at P<0.001 level. This finding can be attributed to the fact that the soils of both sides are formed on different ophiolites. As detailed above, mineralogical composition of these two ophiolitic series were different. It is thought that this difference caused differences in the physical and mechanical properties of the soils. The most easily measurable property of fine-grained soils as the moisture content changes is their variation in consistency, which directly affects strength of soils. Commonly known as Atterberg limits, they have become an inherent part of almost all geotechnical investigations on soils (Kayabali et al., 2016). These limit parameters (LL & PL) and linear and volumetric sihrinkage (COLE & SV) are known to be depend on the soil's mineralogical composition (Sridharan, 2014; Medjnoun and Bahar, 2016). Rather the clayey type of soils are formed by chemical weathering which involves chemical reactions constituting hydration, carbonation and leaching (Zerdi et al., 2016). In both sides, the listed procedures have occurred at different levels. Due to these aspects the LL, PL COLE and SV in the Karacasu soils were generally higher than that in the Göksun-Elbistan soils.

Table 3. Comparison of two locations by independend t test in term of measured variables

Variables	t	Sig. (2-tailed)
LL	-4.623	0.000
PL	-4.977	0.000
COLE	-0.451	0.655
S_V	-4.465	0.000
FC	-4.549	0.000
PWP	-5.785	0.000

LL: Liquid limit, PL: Plastic limit; COLE: Coefficient of linear extensibility, SV: Volimetric shrinkage, FC: Field capacity, PWP: Permanent wilting point

Soil moisture constants (FC & PWP) are affected by inherent and dynamic soil properties. At the beginning of the inherent properties are the clay mineralogy and texture, at the beginning of the dynamic properties is the soil organic matter content. In the present study, both site soils were statistically different in terms of FC and PWP. These differences can attributed to the fact that measured variables are affected by inherent and dynamic soil properties, and those properties were different in both ophiolith area. Moisture percentages at FC and PWP are influenced by distribution of primary soil particles, soil mineraogy and soil organic matter content (Gülser and Candemir, 2015).

To explain relations between measured variables and soil organic matter and textural fractions, correlation matrices have been prepared and presented in Tables 4 and 5. In the soils of Göksun-Elbistan district, SOM-LL and SOM-PL relations were satatiscially significant (P< 0.01). All relations between sand content and measured variables were statistically significant at the different significance level. All relations between clay content and measured variables were statistically significant (P<0.01) except for Clay-PL. In addition, correlations of the measured variables with each other were found to be significant (Table 4).

In the soils of Karacasu district, the relationships between SOM and Atterberg limits were found significant as statisticially. All relations between sand content and measured variables were statistically significant (P<0.01). All relations between clay content and measured variables were also statistically significant at the different significance levels. In addition, correlations of the measured variables with each other gave high correlation coefficients, and these relations were found as statistically significant at the significance level of P<0.01 (Table 5). The results of this study are consistent with those of the studies mentioned above.

Table 4. Correlation matrix of data obtained from Göksun-Elbistan district

	Correlation coefficients and significance levels									
Variables	SOM	Sand	Clay	Silt	LL	PL	COLE	S_V	FC	PWP
OM	1	-0.387	0.201	0.532*	0.596**	0.680**	0.276	0.259	0.327	0.224
S	-0.387	1	-0.914**	-0.806**	-0.700**	-0.488*	-0.835**	-0.687**	-0.899**	-0.838**
C	0.201	-0.914**	1	0.496*	0.754**	0.448	0.825**	0.812**	0.885**	0.900**
Si	0.532*	-0.806**	0.496*	1	0.396	0.389	0.582*	0.286	0.633**	0.479*
PL	0.680**	-0.488*	0.448	0.389	0.786**	1	0.570*	0.497*	0.520*	0.495*
LL	0.596**	-0.700**	0.754**	0.396	1	0.786**	0.765**	0.805**	0.831**	0.832**
COLE	0.276	-0.835**	0.825**	0.582*	0.765**	0.570*	1	0.872**	0.885**	0.921**
S_V	0.259	-0.687**	0.812**	0.286	0.805**	0.497*	0.872**	1	0.823**	0.861**
TK	0.327	-0.899**	0.885**	0.633**	0.831**	0.520*	0.885**	0.823**	1	0.935**
DSN	0.224	-0.838**	0.900**	0.479*	0.832**	0.495*	0.921**	0.861**	0.935**	1

SOM: Organic matter content, S: Sand content, C: Clay content, Si: Silt content, LL: Liquid limit, PL: Plastic limit; COLE: Coefficient of linear extensibility, SV: Volimetric shrinkage, FC: Field capacity, PWP: Permanent wilting point

Table 5. Correlation matrix of data obtained from Karacasu district

	Correlation coefficients and significance levels									
Variables	SOM	Sand	Clay	Silt	LL	PL	COLE	S_V	FC	PWP
OM	1	-0.500*	0.372	0.225	0.544*	0.596**	0.493*	0.539*	0.298	0.474*
S	-0.500*	1	-0.809**	-0.348	-0.717**	-0.618**	-0.682**	-0.751**	-0.739**	-0.779**
C	0.372	-0.809**	1	-0.270	0.688**	0.554*	0.757**	0.794**	0.614**	0.730**
Si	0.225	-0.348	-0.270	1	0.077	0.128	-0.090	-0.037	0.231	0.111
PL	0.596**	-0.618**	0.554*	0.128	0.950**	1	0.628**	0.850**	0.826**	0.910**
LL	0.544*	-0.717**	0.688**	0.077	1	0.950**	0.719**	0.922**	0.900**	0.954**
COLE	0.493*	-0.682**	0.757**	-0.090	0.719**	0.628**	1	0.796**	0.621**	0.751**
S_V	0.539*	-0.751**	0.794**	-0.037	0.922**	0.850**	0.796**	1	0.799**	0.902**
TK	0.298	-0.739**	0.614**	0.231	0.900**	0.826**	0.621**	0.799**	1	0.947**
DSN	0.474*	-0.779**	0.730**	0.111	0.954**	0.910**	0.751**	0.902**	0.947**	1

SOM: Organic matter content, S: Sand content, C: Clay content, Si: Silt content, LL: Liquid limit, PL: Plastic limit; COLE: Coefficient of linear extensibility, SV: Volimetric shrinkage, FC: Field capacity, PWP: Permanent wilting point

Conclusion

In this study, it was concluded that the physical properties of the soils developed on the mantle section of the ophiolitic suite from the Karacasu region in Kahramanmaraş province and the crustal rocks that in the vicinity of Göksun-Elbistan in the north of the city were different. It was found that the LL, PL FC, PWP and LV values of the soils formed on the Karacasu ophiolites were higher than that of the soils formed on the Elbistan-Göksun ophiolites. It was determined that the two ophiolitic terrains were statistically different in terms of the measured variables except the COLE value. These differences were attributed to the fact that the ophiolites in the Karacasu area have been further altered than the ophiolites in the Göksun-Elbistan area. It was thought that this alteration difference was due to the different mineralogical composition of the two ophiolitic areas, in accordance with the changing mineralogical properties, soil characteristics of the two areas changed too.

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