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MORPHOLOGY, PHYSICO-CHEMICAL CHARACTERISTICS AND CLASSIFICATION OF TWO VERTISOLS IN BAFRA AND ÇARŞAMBA DELTA PLAINS

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Abstract: The name of Vertisol is derived from Latin "vertere" meaning to invert, thus limiting the development of classical soil horizons. These soils have the capacity to swell and shrink, inducing cracks in the upper parts of the soil and distinctive soil structure throughout the soil. The formation of these specific features are caused by a heavy texture, a dominance of swelling clay in the fine fraction and marked changes in moisture content. The swell-shrink behavior is attributed to the wetting and drying of the soil mass. In this study, morphology, physico-chemical characteristics and classification of two vertisols that were formed on alluvial delta plains, were investigated. The first one has been formed on the Bafra Plain found in the Kızılırmak Delta and located in the central Black Sea region of Turkey. The soil is very deep, color ranges from dark olive brown to very dark grayish brown (in dry and wet conditions) and clay content is between 53-63 % within the one meter. The second pedon has been formed on the Çarşamba Plain found in the Yeşilırmak Delta and located in the central Black Sea region of Turkey. This pedon has also more than one meter depth, clay content changes between 53-56 %. However, this pedon has lighter color than other one. Slickensides, clay cutans and crack of 3-5 cm wide extends beyond one meter were observed in both pedons. According to Soil Taxonomy and FAO-Unesco Soil Map of the World Legend classification systems, the pedon formed on Bafra delta plain was classified as Chromic Endoaquert sub group and Chromic Vertisol soil unit while, the other pedon formed on Çarşmaba delta plain was classified as Typic Haplustert sub groups and as Eutric Vertisol soil unit, respectively.
Key Words: Vertisol, Soil morphology, Soil classification, Bafra and Çarşamba delta plains

1. INTRODUCTION

The name of vertisol is derived from Latin "vertere" meaning to invert, thus limiting the development of classical soil horizons (Ahmad, 1983). These soils have the capacity to swell and shrink, inducing cracks in the upper parts of the soil and distinctive soil structure throughout the soil (Ahmad and Mermut, 1996). The formation of these specific features are caused by a heavy texture, a dominance of swelling clay in the fine fraction and marked changes in moisture content (Hubble, 1984). The swell-shrink behavior is attributed to the wetting and drying of the soil mass.

Vertisols are described by Glossary of Soil Science Terms (SSSA, 1997) as "mineral soils that have 30 % or more clay, deep wide cracks when dry and either gilgai microrelief, intersecting slickenside or wedge-shaped structural aggregates tiled at an angle from the horizon. It was added as an order in US system of soil taxonomy.

Vertisols, one of the twelve established soil orders, are clay soils with unusual and interesting properties. They cover more than 350 million hectares of land in the world. Because of their very small particle size and high surface area, these soils have higher physical and chemical reactivity than other soils (Ahmad and Mermut, 1996). Depressions and level to undulating areas, mainly in tropical, semi arid to sub humid and Mediterranean climates with and alternation of district wet and dry seasons. An estimated 150 million hectares is potential crop land (Driessen and Dudal, 1991). According to a map called the Turkey Soil Zones Map at the scale of 1:2.000.000 prepared from the results of the Turkey Development Soil Maps Survey at a scale of 1:100.000, Vertisols comprise 598,693 hectares or 0.86 percent of the land area of Turkey (Anonymous, 1999; Özsoy and Aksoy, 2007).

The aim of this study was to investigate the formations and chemicals, physicals and morphological characteristics of Vertisols formed on alluvial delta plains.

2. MATERIAL AND METHODS

This study was carried out in the Bafra and Çarşmaba Plains found in the Kızılırmak and Yeşilırmak deltas located in the central Black Sea region of Turkey (Figure 1). The Bafra plain is far 30 km from north of the Samsun province and Çarşamba palin is far 50 from east of the Samsun province. The current climate in the both of the study area is semi-humid. According to Soil Survey Staff (1999), soil temperature regime is mesic in both delta plains and moisture regimes of Profile 1 and Profile 2 are also aquic and ustic. The mean annual temperature, rainfall and evaporation are 13.6 ºC, 764.3 mm and 726.7 mm respectively in Bafra plain while, the mean annual temperature, rainfall and evaporation are 14.3 ºC, 1045.2 mm and 739.1 mm respectively in Çarşamba plain. These areas are mainly flat and slightly sloped (0-2.0 %) and used for rice cultivation.

Two vertisol profiles were selected for this study from two delta plains. Morphological properties of these two soil profiles in the field were identified and sampled by genetic horizons and classified according to Soil Survey Staff (1999). Seven disturbed and undisturbed soil samples were taken to investigate for their physical and chemical properties at the laboratory. Undisturbed soil samples were taken by using a steel core sampler of a 100 cm^3 volume. Dry bulk density was determined by the core method (Blake, 1965). Disturbed soil samples were dried under atmospheric condition and passed through sieve had necessary opening to prepare for laboratory analysis.

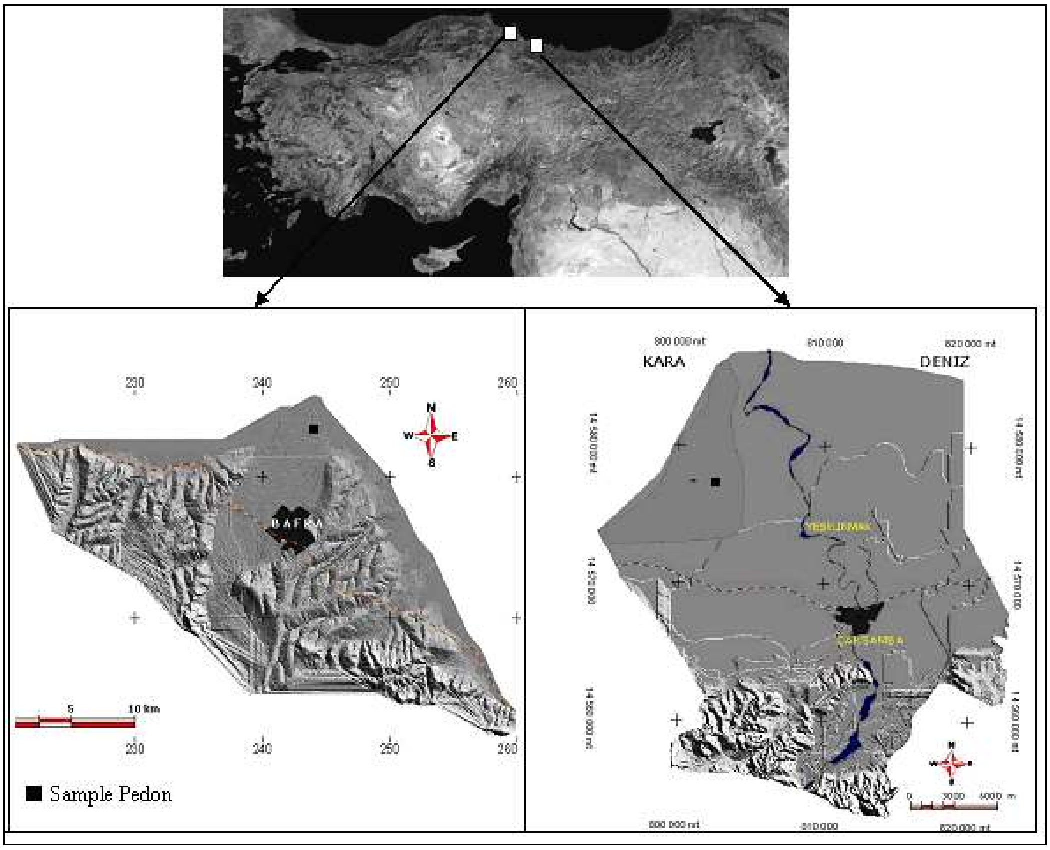


Figure 1. Locations of the soil pedons on Bafra and Çarşamba delta plains

In disturbed soil samples, particle size distribution was determined by the hydrometer method (Bouyoucos, 1951). Soil reaction (pH), electrical conductivity (EC) and $CaCO_3$ content were determined by standard procedure (Soil Survey Staff, 1993). Exchangeable cations and cation exchange capacities (CEC) were measured using a 1 N NH_4OAc (pH 7) extraction method (Soil Survey Laboratory, 1992). Organic matter content was determined using the Walkley-Black wet digestion method (Nelson and Sommers, 1982). Coefficient of linear extensibility (COLE) was determined according to Soil Survey Staff (1999). Atterberg limits were determined according to Soil Survey Laboratory (1992).

3. RESULTS AND DISCUSSION

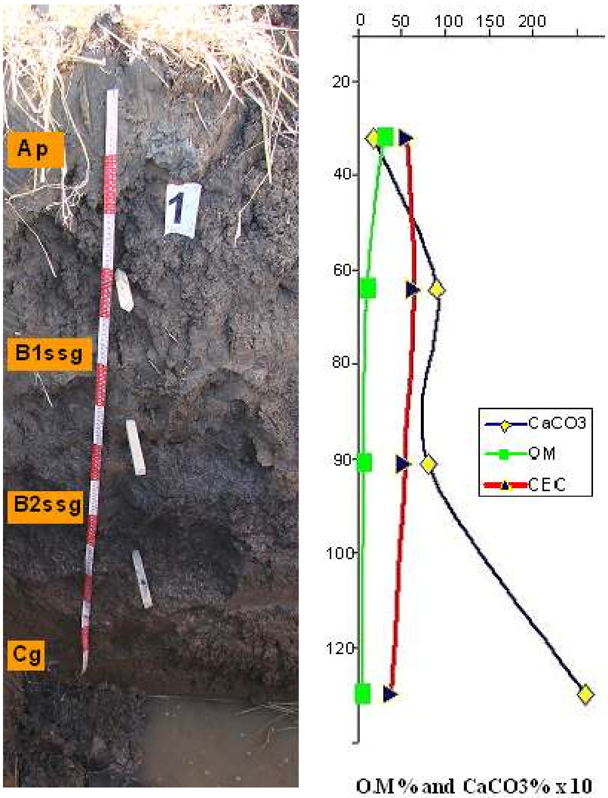
Vertisols are typically found in lower landscape positions such as dry lake bottoms, river basins, lower river terraces, and other lowlands that are periodically wet in their natural state (FAO/ISRIC, 2006). Morphological characteristics of two vertisols that were formed on two alluvial delta plains are presented in Figure 2 and Figure 3. Ahmad and Mermut (1996), Nico (2002) and Ekinci *et al*. (2004) stated that many vertisols have deep and dark topsoil. Worthy of consideration is that the dark color associated with many vertisols is not due to high organic matter contents but rather due to the intense mixing of organic matter with clay and parent material that has ferromagnesian minerals. This case can be seen in Profile 1. Color of this soil in hue changed 10YR and 2.5Y, value was 3 (dry and moisture conditions) in one meter depth. On the other hand, Profile 2 has lighter color values that change from 4 to 6 when dry and wet conditions. Profile 1 has endosaturation condition and redoximorphic features. Griffin *et al.* (1992) also studied watertable movement, soil saturation and reduction in three wetland soil profiles in Texas. One of these soils classified as Entic Pelludert, had a seasonal movement of the watertable between 10 and 130 cm from surface, temporary saturation and reduction and redoximorphic feature. The type of saturation was endosaturation. However, Profile 2 has no watertable and redoximorphic feature. Cracks are a unique feature in soils with strong shrink–swell potential and are used as one of the criteria in defining vertisols and vertic intergrades in soil taxonomy (Soil Survey Staff, 1999). Deep profiles, high amount of smectite clay with its strong potential to swell and shrink that leads to be slickensides, and crack of 3-5 cm wide extends beyond one meter were observed in both pedons.

Physico-chemical characteristics and classification of two vertisols are given in Table 1 and Table 2. The data on particle size distribution indicate that the two pedons have more than 50 % clay content throughout their profiles. In addition, the clay content was increased in the sub horizons. Hydraulic conductivity is too low for both vertisols. The bulk density ranged 1.23-1.59 g cm^{-3} in the Chromic Endoaquert while, Typic Haplustert has 1.27-1.52 g cm^{-3}. It was generally high in surface horizons and decreased with depth in all pedons. High bulk density and compaction in surface horizons may be due to rice cultivation. Soil organic matter content in surface horizon of Profile 1 is 2.75 % and it is greater than organic matter of Profile 2. Organic matter content tended to decrease with depth in two vertisol pedons. The CEC is very high in both pedons due to high clay content. CEC of Profile 1 varies from 38.1 to 62.9 $cmol_c$ kg^{-1} and values of CEC are between 67.3 and 69.2 $cmol_c$ kg^{-1} in the Profile 2. When lime contents of both profiles are investigated from the tables, it can be seen that profile 2 has more $CaCO_3$ along the profile ($CaCO_3$ 6.65-15.47%). The reason is transportation and accumulation of calcareous material around this region. Lime content of profile 1 was found to be low (1.80-8.7%). The reason of low lime content could be attributed to parent material and leaching of calcium by high rainfall from the profile. The pH of the soils ranged from 7.56 to 8.05. Therefore soil reaction is neutral or smooth alkaline reaction. The electrical conductivity values are invariably low ranged from 0.55 to1.73 dS m^{-1}. The exchangeable dominant cataions are Ca^{2+} and Mg^{2+} and they changed 28.10-51.75 $cmol_c$ kg^{-1} and 10.0-18.25 $cmol_c$ kg^{-1}, respectively. Sodium varied from 0.04 to 0.17 $cmol_c$ kg^{-1}. Base saturation was 100 % throughout all the profiles, due to the alkaline parent material and climate. Problem related to salinity and alkalinity was not found in the studied Vertisols. The clay contents of the Vertisols were generally more than 50 % throughout to profile. They are especially rich in smectitic clay minerals reason to have 1-4 cm wide cracks at the surface of the profiles in summer time and to form slicensides that produced by one mass sliding past another with polished and grooved surface due to changes in moisture content. Based on morphological, physicochemical analysis and soil moisture regime, soil profiles were classified according to Soil Taxonomy (Soil Survey Staff, 1999) and FAO-Unesco Soil Map of the World Legend (FAO/ISRIC, 2006) classification systems as Chromic Endoaquert and Typic Haplustert sub groups and as Chromic and Eutric Vertisol soil units, respectively. Atteberg limits and some engineering properties of profiles are presented in Table 3. According to Table 3, coefficient of linear extensibility (COLE) values are high for both profiles. Beside of high smectite type clay contents of all profiles, clay content of profile 1 is greater than clay content of profile 2 in one meter depth therefore COLE value of profile 1 is classified in the upper limit for Vertisols. Both profiles have very high liquid and plastic limit values (Table 3). Soils with high liquid limits are known to have high clay content and low bearing capacity. High amount of clay and their high surface areas in profile 1 caused greater plasticity index. Soils with high plastic limits have higher capacity of swelling and shrinking. As a result hydraulic conductivity decreases and cohesion increases. The highest PI values are 46.1 and 43.7 for profiles 1 and 2 respectively. In spite of very close activity values of both profiles, deeper horizons (between 64 and 101 cm) of profile 1 has higher activity values than those of profile 2. According to Cassagranda (1936) plasticity cards, both pedons were classified into high plastic inorganic clay.

4. CONCLUSION

Large areas of Vertisols in the semi-arid tropics are still unused or are used only for extensive grazing, wood chopping, charcoal burning and the like (FAO/ISRIC, 2006). These soils have considerable agricultural potential, but adapted management is a precondition for sustained production. The comparatively good chemical fertility and their occurrence on extensive level plains where reclamation and mechanical cultivation can be envisaged are assets of Vertisols. Their physical soil characteristics and, notably, their difficult water management cause problems. The physical properties and the soil moisture regime of Vertisols represent serious management constraints. The heavy soil texture and domination of expanding clay minerals result in a narrow soil moisture range between moisture stress and water excess. Tillage is hindered by stickiness when the soil is wet and hardness when it is dry. The susceptibility of Vertisols to waterlogging may be the single most important factor that reduces the actual growing period. Especially due to those properties, these vertisol soils have been generally used for rice cultivation in the study area. On the other hand, this case is not suitable other plants. Zero till is commonly advocated as a preferred cropping system to conventional, multicultivation practices. Zero till is particularly attractive on clay soils to minimize compaction and induce natural structure formation (Özsoy and Aksoy, 2007). In particular, the soil structure of Vertisols has strong potential to attain optimal conditions for plant growth through activation of their inbuilt resiliency via shrink-swell cycles (McGarry, 1996; Pillai and McGarry, 1999). It is accepted that the major purposes of tillage are to reduce bulk density and soil strength and to control pests and diseases (Culpin, 1981; Hill, 1990). However, soil cultivation affects soil quality in various ways. With high clay content, cultivation may lead to the formation of a hard pan below the plough layer that restricts root penetration and downward movement of water (Singh and Singh, 1996). Hence, many researchers strongly recommend that close attention should be paid for the soil cultivation, irrigation system and time depending on the these soil types.

Profile 1. **Coordinate:** 4615703 N-747513 E **Soil Classification**: Chromic Endoaquert



Horizon Definition

Very dark grayish brown (10YR 3/2, moist), very dark grayish brown (10YR 3/2, dry); clay; strong, medium, granular structure; sticky and plastic, very hard; 1-5 cm wide cracks; rare thin roots; wavy, definite border

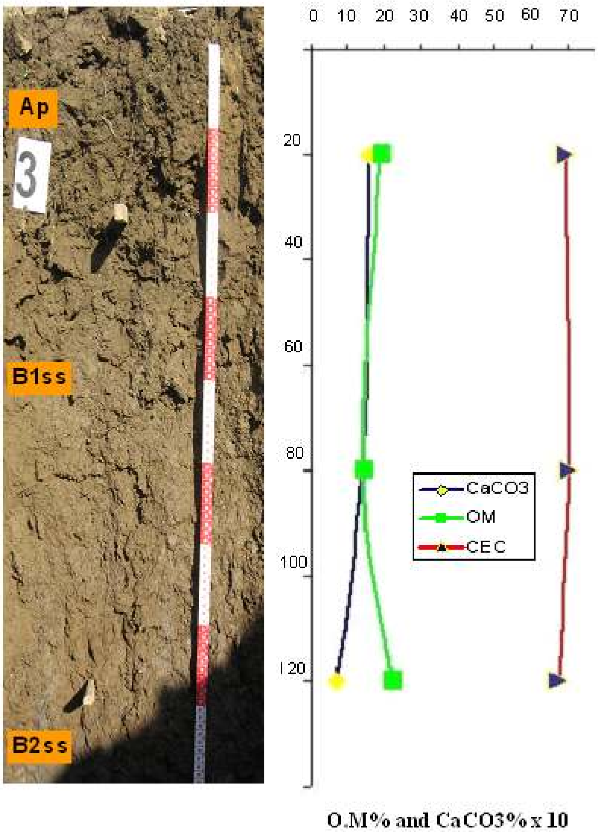
Very dark grayish brown (2.5Y 3/2, moist), dark olive brown (2.5Y 3/3, dry); clay; strong, medium, subangular blocky structure; very sticky and very plastic, very hard; rare thin roots; 1-3 cm wide cracks and slickensides; increasing humidity, wavy, marked border

Very dark grayish brown (2.5Y 3/2, moist), dark olive brown (2.5Y 3/3, dry); clay; strong, medium, subangular blocky structure; very sticky and very plastic, very hard; rare thin roots; sporadic cracks and slickensides; high humidity; wavy, marked border; redoximorphic features

Yellowish brown (10YR 5/4, moist), light yellowish brown (10YR 6/4, dry); clay; massive structure; very sticky and very plastic, very hard; redoximorphic features; existing groundwater

Figure 2. Morphological properties of the Chromic Endoaquert in Bafra Delta Plain

Profile 3. **Coordinate :** 4572207 N-296125 E **Soil Classification**: Typic Haplustert



Horizon Definition

Olive brown (2.5Y 5/4, moist), light yellowish brown (2.5Y 6/4, dry); clay; strong, medium and great structure; very plastic and very sticky, very hard; very rare thin and medium roots; 1-4 cm with cracks, wavy, definite border

Brown (10YR 4/3, moist), light yellowish brown (2.5Y 6/3, dry); clay; strong, medium and great subangular blocky and medium prismatic structure; very sticky and very plastic, very hard; 1-3 cm with cracks; sporadic slickensides; increasing humidity, wavy, border

Brown (10YR 4/3, moist), light olive brown (2.5Y 5/3, dry); clay; strong, medium and great, subangular blocky and medium prismatic structure; very sticky and very plastic, very hard; sporadic slickensides; increasing humidity

Figure 3. Morphological properties of Typic Haplustert in Çarşamba Delta Plain

Table 1. Chemical properties of the Chromic Endoaquert (Profile 1)

Horizon	Depth (cm)	pH*	EC* (dS m^{-1})	Salt (%)	$CaCO_3$ (%)	O.M (%)	CEC** $cmol_c\ kg^{-1}$	Exchangeable cations ($cmol_c\ kg^{-1}$)			
								Na^+	K^+	Ca^{++}	Mg^{++}
Ap	0-32	7.56	1.73	0.10	1.80	2.75	56.8	0.09	0.03	40.00	12.50
B1ssg	32-64	7.67	0.94	0.05	8.70	0.90	62.9	0.05	0.01	45.75	14.00
B2ssg	64-101	7.73	0.78	0.04	7.89	0.56	54.7	0.05	0.02	34.00	18.25
Cg	101+	7.74	0.72	0.03	25.59	0.46	38.1	0.04	0.01	28.10	10.00

*pH and EC values were determined in saturation paste; **CEC: Cation exchange capacity

Table 1 Continue. Physical properties of the Chromic Endoaquert

Horizon	Depth (cm)	Color (Moist, Dry)	Particle size distribution (%)				HC* (cm h^{-1})	BD** (gr cm^{-3})
			Clay	Silt	Sand	Class		
Ap	0–32	10YR 3/2, 10YR 3/2	54.3	31.5	14.2	C	0.099	1.47
B1ssg	32–64	2.5Y 3/2, 2.5Y 3/3	53.7	33.3	13.0	C	0.060	1.59
B2ssg	64–101	2.5Y 3/2, 2.5Y 3/3	63.3	27.4	9.3	C	0.300	1.23
Cg	101+	10YR 5/4, 10YR 6/4	33.7	51.3	15.0	SiCL	0.518	-

*HC: Hydraulic conductivity; **BD: Dry bulk density

Table 2. Chemical properties of the Typic Haplustert (Profile 2)

Horizon	Depth (cm)	pH*	EC* (dS m^{-1})	Salt (%)	$CaCO_3$ (%)	O.M (%)	CEC** $cmol_c\ kg^{-1}$	Exchangeable cations ($cmol_c\ kg^{-1}$)			
								Na^+	K^+	Ca^{++}	Mg^{++}
Ap	0–20	7.96	0.58	0.00	15.47	1.87	68.7	0.03	0.020	51.50	15.75
B1ss	20-79	8.05	0.55	0.04	14.74	1.41	69.2	0.06	0.011	51.75	14.50
B2ss	79+	7.95	1.49	0.10	6.65	2.21	67.3	0.17	0.019	51.25	14.50

*pH and EC values were determined in saturation paste; **CEC: Cation exchange capacity

Table 2 Continue. Physical properties of the Typic Haplustert

Horizon	Depth (cm)	Color (Moist, Dry)	Particle size distribution (%)				HC* (cm h^{-1})	BD** (gr cm^{-3})
			Clay	Silt	Sand	Class		
Ap	0–20	2.5Y 5/4, 2.5Y 6/4	55.0	38.5	6.5	C	1.659	1.52
B1ss	20-79	10YR 4/3, 2.5Y 6/3	53.2	38.7	8.1	C	0.895	1.33
B2ss	79+	10YR 4/3, 2.5Y 5/3	56.6	32.2	11.2	C	0.260	1.27

*HC: Hydraulic conductivity; **BD: Dry bulk density

Table 3. Atterberg limits and some engineering characteristics of two vertisol pedons

Profile 1. Chromic Endoaquert (Bafra Delta Plain)								Profile 2. Typic Haplustert (Çarşamba Delta Plain)							
Horizon	Clay (%)	COLE*	LL**	PL***	PI****	Activity	Cassagranda pl. chart	Horizon	Clay (%)	COLE	LL	PL	PI	Activity	Cassagranda pl. chart
Ap	54.3	0.20	61.7	27.7	33.9	0.62	High pl. inorg. clays	Ap	55.0	0.13	51.6	25.1	26.5	0.48	High pl. inorg. clays
B1ssg	53.7	0.14	56.8	24.5	32.3	0.60	High pl. inorg. clays	B1ss	53.2	0.15	54.0	27.5	26.5	0.50	High pl. inorg. clays
B2ssg	63.3	0.20	69.4	23.3	46.1	0.77	High pl. inorg. clays	B2ss	56.6	0.18	73.6	29.9	43.7	0.73	High pl. inorg. clays
Cg	33.7	0.06	36.8	19.0	17.8	0.53	Medium pl. inorg. clays								

*COLE: Coefficient of linear extensibility; **LL: Liquid limit; ***PL: Plastic limit; ****PL: Index of plastic

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