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GENETIC PANS OF THREE SOILS OF THE SOUTHERN COASTAL PLAINS OF THE UNITED STATES

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An investigation was undertaken to determine morphological, physical, chemical, and mineralogical properties of pans having fragic characteristics in horizons of selected Southern Coastal Plain Soils. Soil series involved were Carnegie (Plinthic Paleudults), Cowarts (Typic Hapludults) and Irvington (Plinthic Fragiudults). Pans were strongly indurated at the top and hardness gradually decreased with depth. Pans were firm when moist and very hard when dry and ranged from 15 to 45 cm in thickness. There was no evidence that particle size distribution was related to pan formation. Organic matter Content, pH, and available P of the epipedon were higher than subsurface horizons although magnitude varied from soil to soil. Cation exchange capacity was fairly consistent in a given horizon for each pedon and was related to organic matter and clay content. Exchangeable Mg content of pans was higher than exchangeable Ca. Pans did not influence the distribution of exchangeable Na, K, Zn, Fe, and Mn. Horizons having fragic characteristics were not related to gross soil mineralogy or clay mineralogy. Close packing of particles and possible surface tension effects due to the structure of the water molecule apparently influenced the bonding which resulted in the brittleness in the pan formations. (Key words: Genetic pans, Gragipans, pans, Sub surface horizon).

Fragipans are considered genetic soil horizons (soil survey staff 1973). They are subsurface features which may vary widely in thickness. Excepton nearly level topography, fragipans usually occur 25 to 100 cm below the surface of the soil. On very level areas, the top of the pan may be within 35 cm of the surface (Winters and simonson 1951). Usually pans nearer the surface are more distinct than those deeper in the pedon. The presence of a pan in a soil has an unfavorable influence on plants by restricting root growth, either through mechanical impedance or by creating a high water table (Prasad and Perkins 1978) during parts of the year. The critical depth of a Pan depends on the type of plants. For many shallow rooted plants, the influence diminishes rapidly when the pan occurs at depths greater than 50 Cm (Grossman and Carlisle 1969).

Fragipans have been reported to have low pH values and correspondingly low base saturation (Jha and Cline 1963. Total quantities of Ca, Mg, K, and P in the pans are similar to those in other subsurface horizons (Winters and Simonson 1951). Fragipan development seems unrelated to the mineralogy of the sand and silt fraction (Carlisle *et al* 1957) The clay mineralogy of fragipans is similar to the clay mineralogy of horizons in associated soils without pans (Grossman and Carlisle 1969).

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Management problems due to pans do not lie in any single feature, but in a group of attributes which together make it a pan. The purpose of this paper was to study selected characteristics of genetically formed pans frequently referred to as fragipans and associated horizons in three Southern Coastal plain soils.

MATERIALS AND METHODS

Study areas are located in the Southern Coastal Plain soil province of Georgia. Three pedons each of the Carnegie (Plinthic Paleudults Cowarts), (Typic Hapludults) and Irvington (Plinthic Fragiudults) series were described and samples from each genetic horizon were collected (Soil Survey Staff 1972). Sand fractions were separated by dry sieving (Soil Survey Staff 1972) and silt and clay particles were separated by centrifugation (Jackson 1956). Soil pH was determined in deionized water and in 0.01 *N* $CaCl_2$ in a 1:2 soil to solution ratio. Organic matter (wet oxidation); Available P (extracted by HCL-H_2SO_4 mixture and determined by the vanadomolydophosphoric yellow color method; Cation exchange capacity (CEC) (1*N* NH_4 OACpH 7), and exchangeable cations were determined by atomic absoption spectrophotometry in the NH_4 OAC leachate as described by Jackson (1958). Exchangeable acidity and percent base saturation calculated based on CEC and the sum of exchangeable cations. Mineralogy of the clay and silt fractions were determined by DTA and X-ray diffraction. A self-recording instrument with 3 mg samples, γ-Al_2O_3 standard, and a temperature increase of 15 C/minute was used in the DTA. For crystalline mineral species identification, samples were analysed on a X ray diffraction unit employing CuK α radiation. Heavy minerals were separated in 0.1 0.05 mm fraction using bromoform (density 2.8 g/cc at 20 C) (Matelski 1951), mounted on a gelatin coated slide and identified with a polarizing microscope (Jackson 1956).

RESULTS AND DISCUSSION

Important morphological features of representative pedons studied are summarized in Table 1, similarity in structure existed in the pan layers. The pans were strongly indurated and brittle at the top which gradually decreased with depth. Open cracks in the pans were not evident. Pans were divided into large prism-like structural units by approximately vertical zones of light colored streaks. On a horizontal section through the pan, light colored streaks formed a polygonal pattern. The pans were firm when moist and very hard to extremely hard when dry. Thickness of the pans ranged from 15 to 45 cm. Morphologically, the pans are more strongly expressed in the Irvington than in the Carnegie and Cowarts soils. Morphological features of horizons containging pans conform to the diagnostic features of fragipans described (Jha and Cline 1963, and Lozet and Herbilon 1971).

Data in Table 2 suggest significant eluviation of clay from the epipedon to the subsurface horizons percentages of clay free sand among horizons indicate that the parent material for the existing soil was uniform throughout. In general fragipans tend to be medium textured

(Grossman and Carlisle 1969), however textural class usually depends on parent material and degree of weathering (Jha and Cline 1963). It has been reported that fragipans have no influence on particle size distribution in soil pedon (Grossman and Carlisle 1969).

Values for PH, organic matter, and available p of the surface layers were higher than for subsurface hoizons although the magnitude varied from soil) Table 3). Uniformly lower pH of soil measured in 0 01 N $CaCl_2$ solution as compared to H_2O signified the dominance of negatively charged exchange sites throughout the pedon. Acid extractable p appeared to be related to organic matter, being relatively high in the surface and consistently low in the remainder of the pedon. (Jha and Cline 1963, and Lozet and Herbilon 1971).

CEC values were fairly consistent in a given horizon for each pedon (Table 3). Values in the A horizons of most soils reflected an accumulation of organic matter. High clay content in the Bt horizons accounts for the relatively high CEC values in these horizons irrespective of the presence or absence of fragipans (Table 2 and 3). Exchangeable Mg content of pans was higher than exchangeable Ca. In general, exchangeable Ca was inversely related to exchangeable Mg in the pedon with depth. Hutcheson *et al* (1959) suggested that high extractable Mg may make clay more susceptible to movement and rearrangement, thereby fostering horizon rigidity. The pan did not influence the distribution of other cations. Data indicated little chemical change from the top of the pan downward and chemical change above the pan appeared to be associated primarily with organic matter and clay content. Jha and Cline (1963) and Lozet and Herbilon (1971) also reported similar results for other soils containing pan formations.

Distribution of heavy minerals with depth is shown in Fig. 1. There was a marked increase in heavy mineral content in the argillic horizons in two of the three pedons of the Carnegie soils. Most of these heavy minerals were hematite. The concentration of hematite was related to the presence of plinthite. A similar trend, but with less magnitude, was also observed in cowarts and Irvington soils. Hematite in the silt fraction of plinthite from Carnegie, Cowarts and Irvington soils has also been reported elsewhere (Wood and Perkins 1976). Nikiforoff *et al* 1948) theorized that significance of weight percentage of heavy minerals in hard pan soils was obscured by the large amounts of secondary iron minerals in the B- horizon and the pan. The light separates were primarily quartz but contained trace amounts of the feldspars. Daniels *et al* (1966) found no relationship between fragipan expression and the percentage of feldspar in the very fine sand fraction for certain soils of North Carolina. Hutcheson *et al* 1959, and Nikiforoff *et.al* 1948 reported that high proportions of quartz do not appear to directly contribute to the prevalence of pans in Coastal plain soils.

In subsurface horizons, kaolinite was the dominant silicate clay mineral of the clay fraction (Table 4). There was a slight increase in kaolinite content with depth in all pedons. Small amounts of goethite, gibbsite, and intergrade micaceous minerals were also identfied. In the fragipon soils of the northeastern United States. 2:1 lattice clay other than montmorillonite predominates, with mica a quantitatively important component (Jha and Cline 1963). Illite. chlorite, and interestratified minerals with some interlayered montmorillonite in the clay fraction of several soils with fragipans were reported from Michigan and northeastern Wisconsin (Grossman and Carlisle 1969). Soils with pans in the middle and lower Mississippi Valley developed in loess contain appreciable amounts of montmorillonitei (Hutcheson *et al* 1959). In Maryland, significant amounts of kaolinite were found in the pan soils (Nikiforoff *et al* 1948).

It has been proposed that silicate clay is the principal bonding agent in fragipans (Hutcheson *et al* 1959, Jha and Cline 1963 and Grossman and Carlisle 1969). Close packing of sand and silt as observed in the current study, is thought to contribute to the effectiveness of clay as a bonding agent through interlocking of sand silt and (Nikiforff *et al* 1948), or like brick and mortar structure (Jha and Cline 1963) or as clay bridges (Lozet anc Herbilon 1971) However, there is no evidence that the clay in fragipans resists disaggregation (Grossman and Carlisle 1969). Hydrated oxides of Fe or Al and amorphous Sioxides have been suggested as bending agents (Grossman and Carlisle 1969, and winters and Simonson 1951). Surface tension effects associated with water films have also been proposed to lend rigidity to soil material (Grossman and Carlisle 1969). Data published by the authors does not indicate that Si, Fe. and Al, or silicate clay minerals are responsible for bonding (Prasad and Perkins 1983). However, close packing of sand and silt particles and possible surface tension effects due to structured water molecules cannot be ruled out. Infrared analysis indicated the presence of hydrogen-bonded hydroxyls which disappeared after heating to 300 C. Brittleness was restored by rehydration under moderate relative humidity. These findings confirm the hypotheses of surface Tension effects associated with water films.

Fragipans have been reported to occur on old geomorphic surfaces (Daniels *et al* 1966; and Nikiforoff *et al* 1948). Inheritance of properties in fragipan development on these surfaces have been suggested however, current studies indcate that pans occurring in Southern Coastal Plain soils do not inherif fragic characteristics from parent material Incremental development of fragipans has been proposed dy Daniels *et al* (1966). but, the incremental development leads to the question of time required to form a fragipan (Grossman and Cartisle 1969) Processes common to a periglacial environment have been implicated in the development of fragipans (Lozet and Herbilon 1971), but arguments against periglacial origin have also been presented (Jha add Carlisle 1969).

In view of the fact that a specific, cementing agent was not detected, and a high bulk density and poor pore size distribution exists (Prasad and Perkins 1978), suggest that the fragic properties

Table 1. Morphological descriptions of representative pedons from Carnegie, Cowarts, and Irvington soils.

Horizon	Depth	Munsell color	Texture	Structure	Consistence	Boundary	Comments
			Carnegies Series				
Apc	0-15	10YR 4/3	s 1	w. fi & med, gr	V Fr	aw	10% Fe conc.
Btc	15-48	10YR 5/8	sc1	w, med, sbK	Fr	gw	5% Fe conc
Btx	48-91	7.5YR 6/6, cm,med,pr 2.5YR 3/6	sc1	mod, med, pt, to sbk	Fi,Br	gw	3% Fe conc. 10% plinthits. 60% brittlenese
Bt1	91-112	10YR 6/8, cm,med,pr 10YR 4/6 and 2. 5YR 4/8, cm,med. di, 2. 5YR 8/2	sc1	W to mod med, sbk	Fr	gw gw	3% plinthite 3% plinthite
Bt2	112-157	10YR 5/8, m,co,pr, 2.5 8/2 and 2.5YR 4/8 cm, med, fa 10YR 6/6	sc1	w, med, sbk	Fr	gw	3% plinthite
			Cowarts Series				
Ap	0-15	2.5YR 6/2	1s	w, fi, gr	V Fr	cs	few quertz gravel
BA	15 36	10YR 5/4	s1	w, fi, gr	Fr	ci	few quartz gravel
Btx	36-56	10YR 5/6, cm, med to co,pr,2 5YR 4/6 and cm, med,fa,10YR 6/6	sc1	mod,co,pt,to mod, med, abk	Br	cw	15% plinthite 60% brittleness
Bt1	56-71	10YR 5/8, fe,fi, fa, 2. 5/YR 4/8, and cm med,d, 5Y 7/2	co sc1	mob,co,pt to. mod, co, abk	Fi	cw	3% plinthite
Bt2	71-152	10YR 5/6, 5YR 6/4 and 5Y 7/1	co sc1	w,co,abk	Fi	—	3% plinthite
			Irvington Series				
Ap	0-33	10YR 4/2	1s	w, med ,gr	V Fr	cw	4% Fe conc.
Btc1	33-41	10YR 6/6	s1	w, med, sbk	Fr	cs	15% Fe conc.
Btc2	41-76	10YR 6/6	sc1	mod,meb,sbk	Fi	gw	40% Fe conc.
Btx	76-155	2 5Y 7/4, fe,med,fa, 10YR 6/8, cm,med,d, 5R 5/8	sc1	mod,med,abk	Fi,Br	—	20% Fe conc. 15% dlinthite. 80% brittleness

Mottles: fe = few, cm = common, m, = many, fi = fine, med, = medium, co = coarse, fa = faint di = distinct, pr = prominent

Texture: s = sand/sandy, c = clay/clayey, l = loam/loamy, co = coarse

Structure: W = weak, mod = moderate, fi = fine, med = medium, co = coarse, gr = granular sbk = sub-angular blocky, abk = angular blocky, pt = platy, pr = prismatic

Consistence: Br = brittle, Fi = firm, Fr = friable, V Fr = very friable

Boundary: a = abrupt, c = cear, g = gradual, i = irregular, s = smooth, w = wavy

Table 2. Particle size distribution in representative pedons from Carnegie, Cowarts, and Irvington Soils.

Horizn	Particle size (mm) 5.0—1.0	1.0—0.5	0.5—0.25	0.25—0.10	0.1—0.05	Total Sand	Total Silt	Total Clay
	%							
				Carnegie Series				
Apc	8	18	24	22	8	80	7	13
Bfc	4	13	17	18	7	59	11	30
Btx	4	14	20	18	7	63	9	28
Bt1	4	14	19	14	6	57	14	29
Bt2	5	15	19	12	5	56	13	31
				Cowarts Series				
Ap	3	7	19	34	14	77	11	12
BA	3	7	16	26	9	61	11	28
Brx	3	9	17	17	7	53	11	36
B1	10	14	17	13	5	59	11	30
Bt2	19	18	13	9	4	63	9	28
				Irvington Series				
Ap	1	4	2	41	15	63	31	6
Btc1	1	3	16	34	12	66	9	25
Btc2	1	3	16	34	11	65	10	25
Btx	1	3	17	20	9	50	26	24

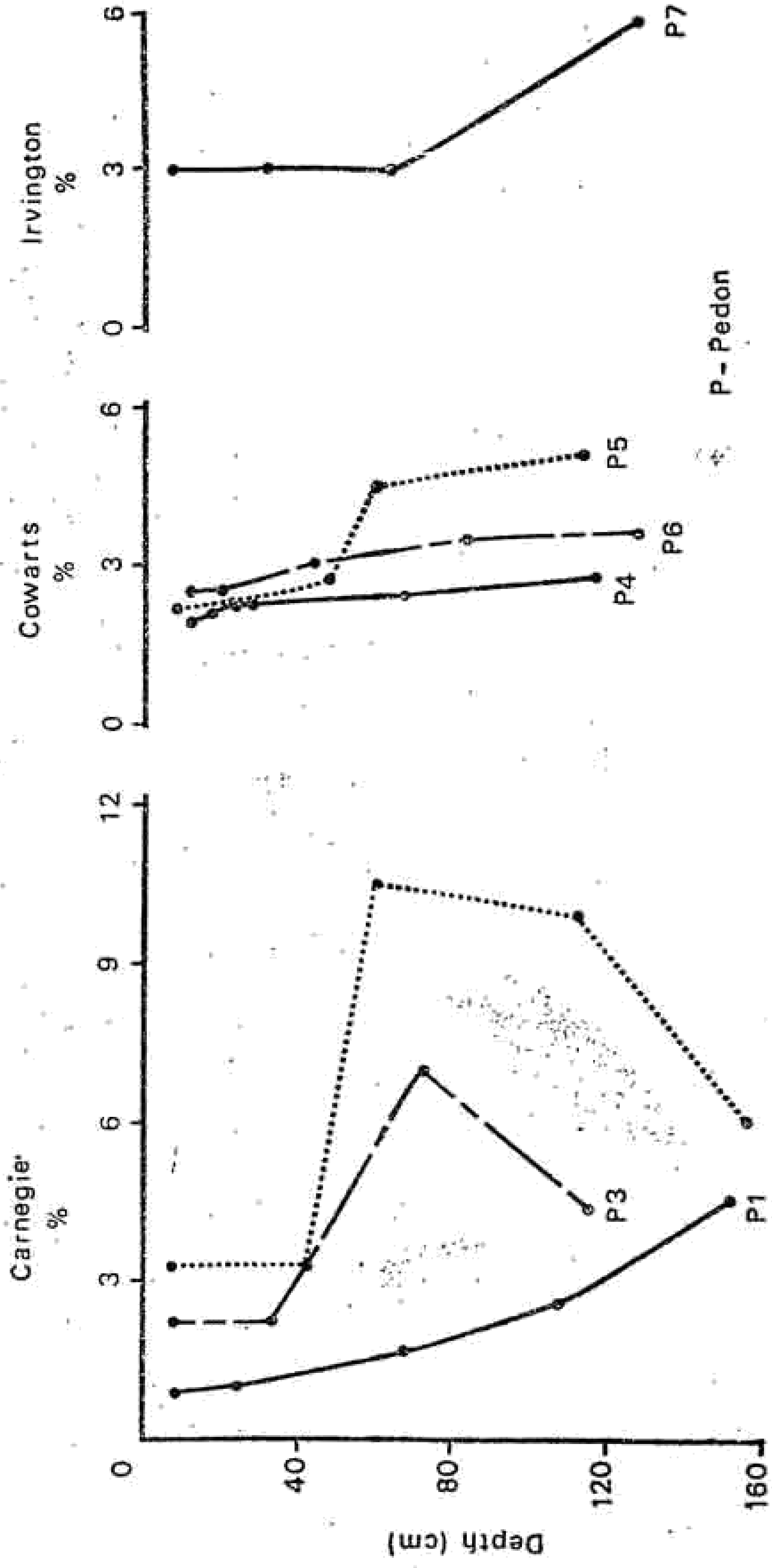
Table 3. Selected chemical properties of selected pedons from Carnegie, Cowarts, and Irvington soils.

	PH (1:2)		Org.		Ext.		Exchangeable							Base
Horizon	H_2O	$CaCl_2$	matter	P	CEC	Ca	Mg	Na	K	Zn	Fe	Mn	acidity	saturation
			(%)	(µg/g)	(meq/100g				)	(µg/g		)	(meq/100g)	(%)
					Carnegie Series									
Apc	5.2	4.1	3.9	8.5	4.4	1.8	0.8	0.8	0.4	2.9	2.0	0.8	0.6	86
Btc	5.1	4.1	0.2	1.8	5.3	1.3	1.1	0.3	0.3	1.0	3.8	0.3	2.3	57
Btx	5.1	4.1	0.2	2.1	6.3	1.0	1.5	0.3	0.2	1.8	3.3	0.3	3.3	48
Bt1	4.9	4.0	0.2	1.8	4.0	0.9	1.0	0.4	0.2	1.3	2.1	0.2	1.5	38
Bt2	4.7	3.9	0.2	0.7	3.5	0.6	0.5	0.4	0.2	1.7	1.4	0.2	1.8	51
					Cowarts Series									
Ap	4.8	4.0	4.4	21.1	5.0	1.4	1.1	0.3	0.5	1.5	2.8	3.0	1.7	66
BA	4.8	3.9	2.0	9.5	4.8	0.9	1.0	0.3	0.2	0.5	3.8	1.4	2.4	50
Btx	4.9	3.9	0.4	0.7	6.0	0.6	1.4	0.4	0.2	0.3	3.4	0.2	3.4	43
Bt1	4.9	3.8	0.3	0.7	5.8	0.2	0.9	0.5	0.2	0.4	2.0	0.2	4.0	31
Bt2	4.6	3.8	0.1	0.7	4.3	0.4	0.8	0.5	0.2	4.7	3.2	0.4	2.4	44
					Irvington Series									
Ap	4.8	4.0	2.3	12.3	4.8	1.2	0.8	0.3	0.5	2.3	2.8	6.5	2.0	58
Btc1	5.1	4.3	0.5	4.2	4.8	1.0	0.9	0.4	0.2	0.8	5.6	0.9	2.3	52
Btc2	4.9	4.1	0.4	1.8	5.0	0.9	1.0	0.4	0.1	0.8	5.1	0.5	2.6	48
Btx	4.8	4.0	0.3	0.7	4.5	0.4	0.5	0.2	0.1	1.1	5.2	0.4	3.3	27

Table 4 Silt and clay minerlogy of representative pedons from Carnegie, Cowarts and Irvington soils.

Horizon	Particle Size (mm)				
	0.5-0.02	0.02-0.005	0.005-0.002	0.002-0.0002	<0.0002
Carnegie Series					
Apc	Q_1*	$Q_1K_4Gi_4$	$K_2Q_3Gi_3$	$K_1Gi_2Q_3$	K_1Gi_2
Btc	Q_1	$Q_1K_4Gi_4Go_4Mi_4$	$K_2Q_3Gi_4Go_4Mi_4$	$K_1Gi_3Go_3Mi_4Q_4$	$K_1Gi_3Go_4Mi_4$
Btx	Q_1K_4	$Q_1K_3Gi_3Go_4Mi_4$	$K_2Q_3Gi_3Go_3Mi_4$	$K_1Gi_3Go_3Mi_4Q_4$	$K_1Go_2Gi_3Mi_4$
Bt1	Q_1K_3	$Q_1K_2Go_3Gi_4Mi_4$	$K_2Q_2Go_3Gi_4Mi_4$	$K_1Go_3Gi_3Mi_4Q_4$	$K_1Go_3Gi_3Mi_4$
Bt2	$Q_1K_3Go_4Gi_4$	$Q_2K_2Go_3Gi_4Mi_4$	$K_2Q_3Go_3Mi_3Gi_4$	$K_1Go_3Gi_3Mi_4Q_4$	$K_1Go_3Gi_3Mi_4$
Cowarts Series					
AP	Q_1K_4	$Q_1K_1Mi_4$	$K_2Q_2Go_3Gi_4Mi_4$	$K_1Q_3Go_2Gi_4Mi_4$	$K_1Go_3Gi_3Mi_4$
BA	$Q_1K_3Go_4Mi_4$	$Q_1K_2Go_3Mi_4$	$K_2Q_3Go_3Gi_3Mi_4$	$K_1Go_3Gi_3Mi_4Q_4$	$K_1Go_3Gi_2Mi_4$
Btx	$Q_1K_3Go_4Gi_4Mi_4$	$Q_1K_2Go_3Gi_4Mi_4$	$K_1Go_3Gi_3Mi_4Q_4$	$K_1Go_3Gi_3Mi_4Q_4$	$K_1Go_3Gi_3Mi_4$
Bt1	$Q_1K_3Go_4Gi_4Mi_4$	$Q_1K_2Go_4Gi_4$	$K_2Q_3Go_3Gi_4Mi_4$	$K_1Go_3Gi_4Mi_4Q_4$	$K_1Go_3Gi_4Mi_4$
Bt2	$Q_1K_2Go_4$	$Q_1K_3Go_4$	$K_1Q_2Go_3Mi_4$	$K_1Go_3Q_2Mi_4$	K_1Go_3
Irvington Series					
AP	Q_1	$Q_1K_4Mi^4$	$Q_2K_3Mi_3$	$K_2Q_3Go_3Mi_3$	$K_1Q_1Go_3M_4$
Btcl	Q_1Mi_4	$Q_1K_3Go_4Gi_4Mi_4$	$K_2Q_3Mi_3Go_4Gi_4$	$K_1Mi_3Q_4Go_4Gi_4$	$K_1Mi_3Go_3Gi_4$
Btc2	Q_1K_4	$Q_1K_3Mi_4Go_4$	$K_2Q_3Mi_3Go_4$	$K_1Mi_3Go_3Q_4$	$K_1Go_3Mi_4$
Btx	$Q_1K_3Go_3Mi_4$	$Q_1K_3Go_3Gi_4Mi_4$	$K_2Q_2Go_3Gi_4Mi_4$	$K_1Go_3Gi_4Mi_4Q_4$	$K_1Go_4Gi_4Mi_4$

* K = kaolinite, Gi = Gibbsite, Go = Goethite, Mi = Intergrade mica, Q = Quartz
1 = >50%, 2 = 50 to 30%, 3 = 30 to 10%, 4 = <10%


Carnegie %
Cowarts %
Irvington %
Depth (cm)
0
40
80
120
160
0
3
6
9
12
0
3
6
0
3
6
P1
P3
P4
P5
P6
P7
P – Pedon

of horizons in southern Coastal plain soil are primarily a result of compression and orientaion of soil particles.

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