

CLAY MINERALOGY OF SOME SILTY SOILS OF THE INNER COASTAL PLAINS OF MISSISSIPPI

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Abstract—The chemical and mineralogical properties of six soils previously believed to be developed from coastal plain sediments were found to be significantly influenced by thin loess overlays and admixtures. The study included two profiles each of the Atwood, Lucedale and Savannah series. Atwood formed primarily in deep loess over coastal plain sediments, Lucedale showed definite loess influence to a depth of 10 in. and possible mixing to a greater depth, whereas the Savannah indicated the presence of slight loess to a depth of 20 in. Both the Atwood and Lucedale soils are well drained, whereas Savannah is moderately well drained and contains a fragipan.

The mineralogy of the coarse clay (2–0.2 μm) appeared to be the most diagnostic feature indicating genetic differences among the soils. Montmorillonite in this clay fraction was most abundant in Atwood, diminished in Lucedale and occurred only in trace amounts in Savannah. In both the Atwood and Lucedale soils very little montmorillonite was found at depths of 35 in. where coastal plain influence apparently predominates. Conversely, aluminous vermiculite–chlorite intergrade minerals were least abundant, in Atwood, increased in Lucedale and occurred in greatest amounts in Savannah.

Accompanying these changes in mineralogy were corresponding changes in the chemical properties. Although no consistent differences in Ca and Mg content were found between the Atwood and Lucedale soils, both Atwood and Lucedale were much higher in exchangeable Ca and Mg than Savannah. Soil pH and base saturation increased in the order Savannah, Lucedale and Atwood.

INTRODUCTION

MANY SOILS in the Coastal Plain of Mississippi contain much silt. Some soil scientists have suggested that these soils have been influenced by loess which occurs west of the Coastal Plain region. Loess is characteristically high in silt. Vanderford *et al.* (1966) have shown that many soils which are definitely of coastal plain origin have high silt contents, therefore, the presence of high silt cannot be considered conclusive evidence of loess influence. In this study an attempt was made to determine the extent of mixing of loess with coastal plain material, both vertically and horizontally, and the extent that loess influences the mineralogy of soil clays.

MATERIALS AND METHODS

Two profiles each of three soil series—Atwood, Lucedale and Savannah—were sampled in the Inner Coastal Plain region of northern Mississippi. The locations of these soils are shown on the map in Fig. 1 in relation to the physiographic regions of the state. At the western edge of the Thick Loess region the loess is often 30–40 ft deep, but decreases in thickness to the east. In the Thin Loess area the underlying coastal plain materials become evident in the lower part of soil profiles. Soils of the Coastal Plain region were formed

predominantly from marine deposits; however, on ridges and higher elevations the presence of a thin loess cap is a very real possibility. The two Atwood profiles fit into this category even though they are located 60 miles from the loess bluff along the Mississippi River Alluvial Plain. The Lucedale and Savannah soils are located about 80 miles from the bluff.

Atwood soils are dark reddish-brown well drained, and occur on nearly level slopes. These soils have 50–80 per cent silt in the upper 36 in. They are classified as Ultic Paleudalfs according to Soil Taxonomy System of the Soil Conservation Service (Soil Survey Staff, 1960). The Lucedale soils are similar to Atwood in color and drainage, but are more acid in reaction and contain less silt in the surface horizons. The Savannah soils are acid, moderately well drained, and have a fragipan at about 24 in. The Lucedale and Savannah are classified in the Rhodic Paleudults and Typic Fragiudults sub groups, respectively.

Soil samples were prepared for mineralogical examination by fractionation into various sizes after oxidation of organic matter (Jackson, 1956), removal of free iron oxides (Mehra and Jackson, 1960) and dispersion with sodium carbonate (Jackson, 1956). Separation into different particle sizes was accomplished by centrifugation and sieving.

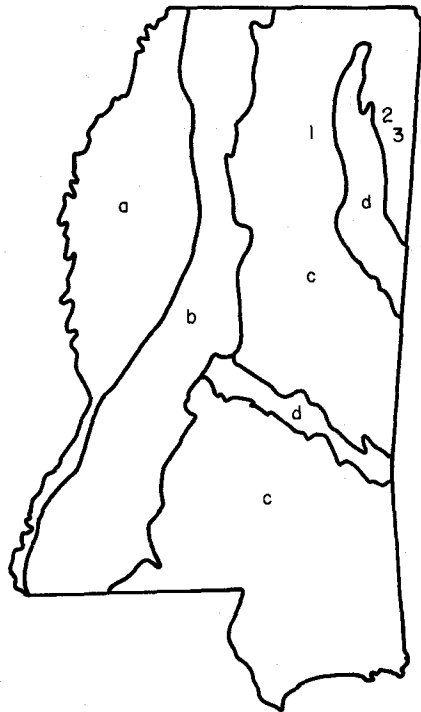


Fig. 1. The major land resource areas of Mississippi are: (a) Mississippi River alluvial plain; (b) Brown loam (loess); (c) Coastal Plain; and (d) Blackbelt (calcareous clays). The location of soil profiles studied are shown by numbers: (1) Atwood; (2) Lucedale; and (3) Savannah.

X-ray examination of fine silts and clays was done with a Norelco Geiger counter spectrometer using Cu K α radiation and Ni filter. Slides of oriented clay were prepared by slowly drying glycerol-solvated samples of K- and Mg-saturated clay on 5 x 5 cm glass slides. Identification of minerals was facilitated by heating K-saturated samples at 300, 525 and 600°C for 4 hr.

Differential thermal analyses were made on selected clay samples. These specimens were Mg-saturated, dried from benzene and equilibrated in a desiccator over a saturated solution of Mg(NO₃)₂ · 6H₂O with an r.h. of 55 per cent. Analyses were run on a Norelco Deltatherm unit with a heating rate of 10°C min⁻¹.

The exchangeable cations K, Na, Ca and Mg were determined after replacement from the soil with N NH₄OAc, by means of an atomic absorption unit. Excess NH₄OAc was removed by washing with water and alcohol, and the salt free soil was digested with NaOH in a Kjeldahl flask. The NH₃ released was collected in H₃BO₃, titrated with H₂SO₄, and the cation exchange capacity calculated. Extractable Al, defined as that Al which could be removed by leaching the soil with N KCl (Lin and Coleman, 1960), was determined colorimetrically with the aluminon methods of Hsu (1963).

RESULTS AND DISCUSSION

The soils reported in this study are from a transition zone between soils of definite loess origin and those of marine origin in the Coastal Plain. In soils where mixing of loess and coastal plain material may have occurred, it is often difficult to assess the relative influence of both materials. Although loess soils are high in silt, this criterion alone may not be valid for separating these mixed soils from silty soils of a different origin. A number of characteristics were examined in an attempt to differentiate between the diverse origins of the soils. The Atwood soils are high in silt and low in sand (Table 1), particularly in the surface horizons. This characteristic and their location on ridges suggest that a cap of loess was deposited over coastal plain material. The Lucedale and Savannah soils, which are located farther from source of loess, also show appreciable silt in the upper 36 and 19 in., respectively. However, it is more meaningful to express the silt on a clay free basis in order to remove the effect of clay migration and formation (Barnhisel *et al.*). Figure 2 shows the silt distribution as a function of depth when expressed in this manner. In the Atwood soil, which contains over 80 per cent silt in the upper 3 ft, there is a general decrease in silt with depth. The high content of silt suggests a loess origin. The upper 36 in. of the Lucedale and upper 19 in. of the Savannah profiles contain 60–80 per cent silt which is believed to indicate loess mixed with coastal plain material. The lower silt

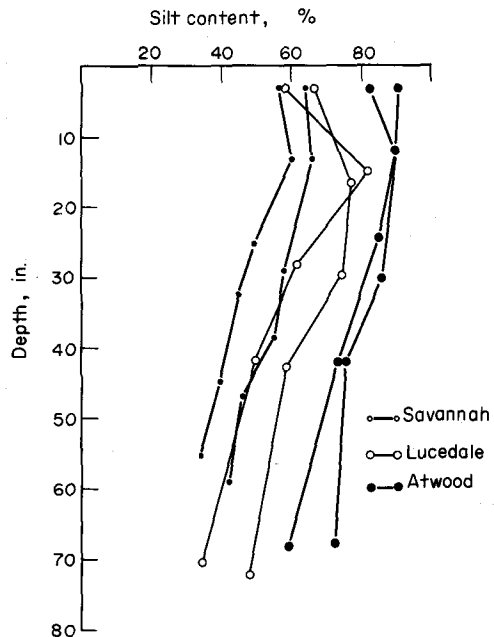


Fig. 2. The silt content, expressed on a clay-free basis of Atwood, Lucedale and Savannah profiles.

Table 1. Chemical and physical properties of soils

Horizon (in.)	Particle size dist. (%)			Ratio* coarse/fine silt	Chemical properties					Free Fe ₂ O ₃ %	Feldspar No. 300 ⁻¹ (gr)
	Sand (2-0.05 mm)	Silt (2-50 μm)	Clay (2 μm)		Ca	Mg	Al	CEC (g)	pH 1:1		
Atwood No. 1—S61 Miss 58-1											
Ap; 0-6	9.1	84.3	6.6	1:1	6.0	0.8		6.3	6.8	1.5	21
B21t; 11-23	6.4	52.0	41.6	1:2	4.8	3.0		10.6	5.7	2.7	15
B22t; 23-37	9.6	58.1	32.3	1:2	1.2	2.3	2.8	8.8	4.7	3.0	14
IIB23t; 37-49	16.7	50.6	32.7	1:2	0.6	1.9	2.7	8.9	4.8	2.8	14
IIB24t; 60-75	18.4	46.5	35.1	1:2	0.8	2.4	1.9	9.4	4.7	2.9	12
Atwood No. 2—S61 Miss 58-2											
Ap; 0-6	14.0	68.2	17.8	1:7	6.2	0.8		7.0	6.6	1.9	24
B21t; 6-18	5.8	58.7	35.5	1:4	10.0	1.2		13.4	6.5	3.4	27
B22t; 18-31	10.6	54.7	34.7	1:1	7.8	1.6		10.7	6.3	3.4	
B23t; 31-45	16.9	46.1	37.0	1:2	6.1	2.3		10.1	6.3	3.5	15
IIB25t; 57-79	25.1	36.2	38.7	1:2	3.7	3.9		10.0	6.3	4.1	8
Lucedale No. 1—S61 Miss 48-1											
Ap; 0-6	29.8	58.7	11.5	1:6	2.5	0.2		4.6	5.5	1.0	20
B21t; 10-23	16.2	53.6	30.2	0.9	5.4	1.6		8.4	5.8	2.4	11
B22t; 23-37	22.1	45.9	32.0	0.9	3.0	1.8	0.5	9.1	5.2	2.8	8
B23t; 37-50	26.7	38.3	35.0	0.9	0.6	1.3	2.5	7.6	4.6	2.9	2
B25t; 65-80	34.0	31.8	34.2	1:0	1.6	2.2	1.2	8.8	4.8	3.0	1
Lucedale No. 2—S61 Miss 48-2											
Ap; 0-6	37.7	50.0	12.3	1:8	2.6	0.8		4.5	5.3	1.0	8
B21t; 9-21	19.6	51.4	29.0	1:5	5.7	1.6		8.6	5.8	2.5	5
B22t; 21-35	27.1	42.6	30.3	1:0	4.5	1.9		8.3	5.6	2.7	9
B23t; 35-48	33.6	33.3	33.1	1:0	3.2	2.0	0.1	7.6	5.3	2.5	3
B25t; 61-80	44.2	23.5	32.3	1:1	0.9	1.2	2.4	7.0	4.8	2.7	2
Savannah No. 1—S61 Miss 48-3											
Ap; 0-7	32.3	58.0	10.7	0.50	1.3	0.8	0.5	4.2	4.5	1.6	4
B21t; 7-19	24.0	47.4	28.1	0.18	3.0	1.7	0.9	7.9	5.0	2.7	2
B23tx; 23-35	29.0	40.4	29.9	0.05	0.9	1.3	3.5	9.0	4.5	2.3	0
B24tz; 35-42	30.7	38.0	30.5	0.17	0.2	1.1	4.0	9.6	4.3	2.7	2
B31; 42-53	38.5	33.1	28.1	0.12	0.1	1.2	3.5	7.5	4.2	2.5	1
B32; 53-65	42.7	31.0	26.5	0.13	0.1	0.6	3.5	6.9	4.6	2.4	1
Savannah No. 2—S61 Miss 48-4											
Ap; 0-7	40.8	52.2	6.7	0.32	2.0	0.5	0.1	3.7	5.5	0.8	11
B21t; 7-19	30.0	46.3	21.4	0.38	1.0	1.9	2.2	8.6	4.7	2.2	3
B23tx; 23-27	40.3	39.4	18.5	0.17	0.1	1.0	2.5	5.5	4.9	1.6	1
B24tx; 27-37	40.2	32.9	24.0	0.16	0.1	1.2	3.6	8.4	4.9	2.3	2
B31; 37-49	45.0	28.4	26.2	0.14	0.1	1.3	4.3	7.5	4.9	2.5	
B32; 49-62	48.0	25.1	24.2	0.45	0.1	1.3	4.5	8.2	4.7	2.5	

* Coarse silt (20-50 μm); fine silt (2-20 μm).

values in the surface horizons of Lucedale and Savannah, relative to horizons immediately below, are probably due to the removal of fine silt by differential erosion.

Vanderford *et al.* (1966) have shown that the silt loessial soils contain a higher percentage of coarser particles, whereas the reverse is true of coastal plain silt. This relation was checked in these soils and the ratio of coarse to fine silt shown in Table 1. Atwood had a ratio of 1:1 or greater throughout the profile whereas Savannah had a value of less than 0.2. The surface

layers of Savannah had slightly higher values suggesting loess influence. Lucedale had intermediate coarse-fine silt ratios, but were closer to Atwood.

Other observations were also made in an attempt to establish the origin of silt. The ZrO content of the fine silt (20-2 μm) was about 0.05 per cent to a depth of 36 in. in Atwood and to a depth of 20 in. in Savannah. Below these depths in both soils the value increased to approx 0.1 per cent. These changes in ZrO content correspond to the previously suggested depths of loess influence. Petrographic microscope examination of the

coarse silt and fine sand showed a higher quartz-feldspar ratio in those soils and horizons which are dominated by coastal plain materials. The grain count of feldspars in the 50–100 μm size fractions is shown in Table 1. Again the Atwood and the surface horizons of Lucedale and Savannah show evidence of loess influence by their higher feldspar count. Kyanite was found in the coastal plain soils, but not in loessial affected horizons.

Although no one criterion is completely satisfactory in separating loess from coastal plain materials, when all characteristics examined are used collectively a reasonable estimate of the extent of the loess influence is obtained. On these bases, it appears that the upper 36 in. of the Atwood soils are definitely of loess origin. Lucedale has some mixing of loess with coastal plain material down to 36 in., whereas the Savannah has slight amounts of loess contamination to depths of 20 in.

Changes in mineralogy of coarse clay (2–0.2 μm) from the predominant loessial to the predominantly coastal plain soils are shown in Figs. 3, 4 and 5. Figure 3 shows the changes in clay mineralogy with depth of the Atwood profile. Montmorillonite was particularly evident in the upper 36 in. of this soil, but was not

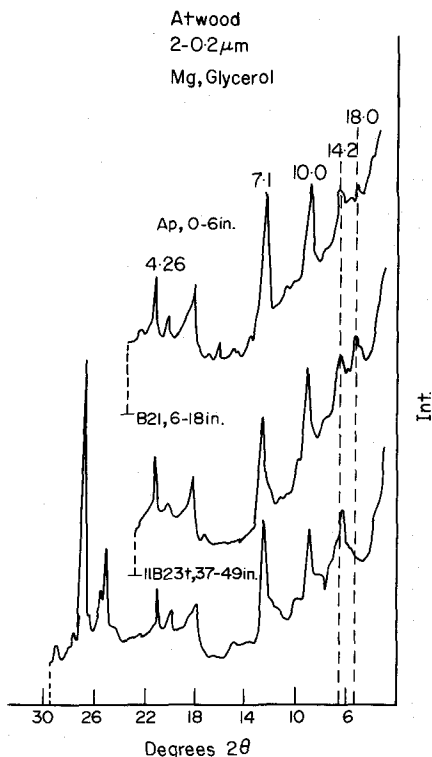


Fig. 3. X-ray diffractions patterns of parallel oriented specimens of the 2–0.2 μm fraction from the Atwood profile. Clay specimens were Mg-saturated and glycerol-solvated.

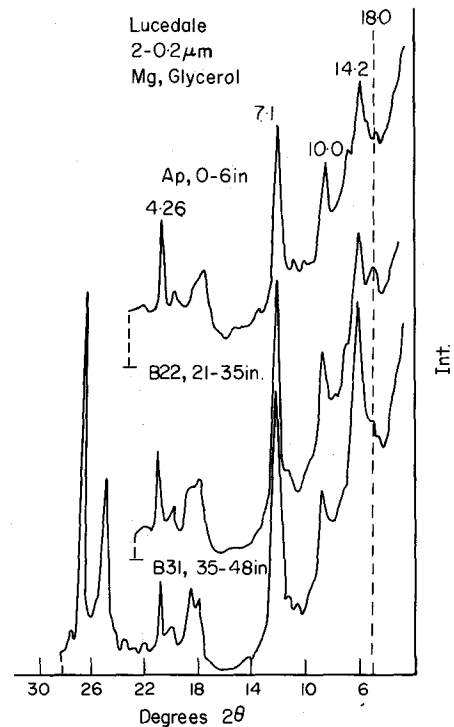


Fig. 4. X-ray diffraction patterns of parallel oriented specimens of the 2–0.2 μm fraction from the Lucedale profile. Clay specimens were Mg-saturated and glycerol-solvated.

found in horizons below this depth. The presence of montmorillonite coincides with those horizons which we have previously concluded to be of loessial origin. Snowden's (1966) work on unweathered loess, which shows montmorillonite to be the dominant clay mineral, gives credence to this assumption. X-ray diffractograms of K-saturated clays showed that the montmorillonite in Atwood collapsed to 14 Å, indicating a high charge density. A 14 Å chlorite-vermiculite intergrade mineral was found in all Atwood horizons, but differed in ease of collapse to 10 Å on heating. The mineral in the surface horizon was difficult to collapse, approaching chlorite in behavior. On the other hand, the 14 Å mineral in the deepest horizon behaved more like vermiculite and collapsed readily to 10 Å on heating. Differential thermal analysis curves of the surface horizon clays showed an endothermic reaction at 400–500°C, which appeared as a shoulder of the kaolinite peak. This reaction was also taken as evidence of the presence of an intergrade mineral (Rich *et al.*, 1955). This endotherm was not observed at the deepest soil horizon. Mica, kaolinite and quartz in Atwood clays did not vary with depth.

The Lucedale soils (Fig. 4), like Atwood, contained a significant amount of montmorillonite in the upper

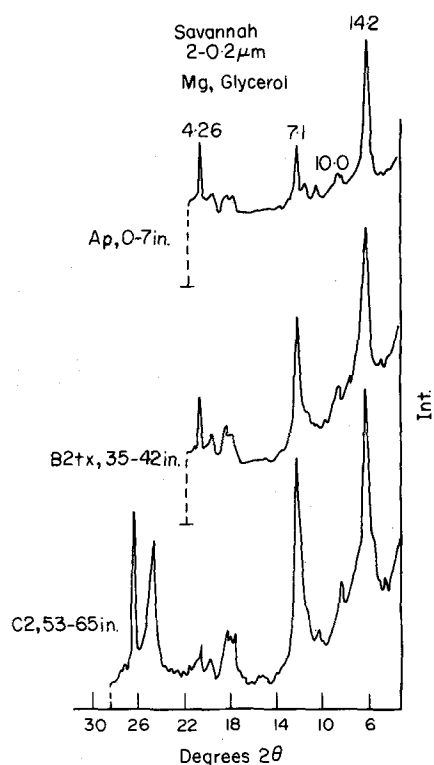


Fig. 5. X-ray diffraction patterns of parallel oriented specimens of 2-0.2 μm fraction from the Savannah profile. Clay specimens were Mg-saturated and glycerol-solvated.

36 in., but only traces below this depth. The 14 Å chlorite-vermiculite intergrade mineral was more prominent in Lucedale than in the Atwood soils. This clay is particularly well developed below the 36 in. level, which corresponds to the coastal plain sediments.

Only a trace of montmorillonite was found in the coarse clay of the Savannah soils (Fig. 5) at all depths. However, the chlorite-vermiculite intergrade mineral increased in amount when Savannah was compared to the Atwood and Lucedale soils. As in the case of Atwood and Lucedale, the amount of intergrade mineral in Savannah increased with depth, and its characteristics changed from partially collapsible at the soil surface to completely collapsible in deeper horizons. Mica, which was prominent in the other soils, was practically absent in Savannah.

The fine clay (<0.2 μm) in all of the soils was somewhat similar in mineralogy (data not shown) with kaolinite and/or halloysite and montmorillonite being principle components. The major differences observed in the X-ray diffraction patterns were broad peaks extending from 7-10 Å in the upper 36 in. of the Atwood and Lucedale soils. This source of the 7-10 Å

peak is interpreted to be halloysite which coincides with the zones of loess influence.

The distribution of the major exchangeable cations in the six soil profiles is shown in Table 1. Calcium and Mg contents were generally higher in Atwood and Lucedale, particularly in the upper 36 in. It is possible that lime could have been applied to these soils; however, it is unlikely that its effect would have extended below 10 in. The pH and Ca content of the surface horizon of Lucedale and Savannah indicate that they have not been limed in recent years. Magnesium increased with depth in most cases and exceeded exchangeable Ca in the deeper horizons of the Atwood and Lucedale and throughout the Savannah profile except for the surface layer. Acidity increases along with increasing Mg and Al. It seems likely that the Mg and Al were released from layer silicate minerals in the acid environment. In the usual weathering profile the more intense weathering occurs at the surface with pH and basic cations increasing with depth. However, the reverse is true in these soils, which again supports the contention that the parent material was acid coastal plain sediments over which was deposited and admixed a blanket of loess.

The increase in extractable Al in Savannah and in the deeper horizons of the Atwood and Lucedale parallels the observed increases in chlorite-vermiculite intergrade. Interlayer cations in these minerals are most likely Al with some Mg. In the deeper, more acid horizons, these cations probably behave as hydrated cations which lose their water on heating and collapse to 10 Å (i.e. characteristic of vermiculite). Closer to the soil surface these 14 Å minerals resist collapse on heating, which suggests that they are approaching chlorite in properties and apparently contain aluminohydroxy interlayers.

CONCLUSIONS

(1) The three soil series discussed in this report were located in the transition zone between loess and coastal plain sediments. The Atwood soils developed primarily in loess to a depth of 36 in. with acid coastal plain material below that depth. Loess was admixed with coastal plain sediments in the Lucedale soils down to 36 in. and Savannah showed some mixing to 20 in.

(2) A close relation was observed between the clay mineral types in coarse clay and origin of the parent materials. Those soils having horizons which were formed mainly from loess contained montmorillonite in appreciable amounts. This was shown for the upper horizons of Atwood and Lucedale profiles. The Savannah soils, which originated primarily from coastal

plain sediments, were dominated by chlorite-vermiculite intergrade minerals with little evidence of montmorillonite, except in fine clays. The lower horizons of the Atwood and Lucedale pedons, which were also of coastal plain origin, were similar to Savannah.

(3) The acidity and exchangeable aluminum of these soils increased with increasing amounts of coastal plain sediments. Under these acid environmental conditions, layer silicate minerals with interlayers of hydrated Al or aluminohydroxy polymers were the stable constituent.

(4) The clay minerals found in these soils are believed to be a reflection of the origin of parent material rather than the *in situ* formation of the clay.

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Résumé—Les propriétés chimiques et minéralogiques de six sols dont on pensait autrefois qu'ils s'étaient développés à partir de sédiments de plaines côtières sont apparues comme étant significativement influencées par de fins recouvrements de loess et par des apports divers. L'étude a porté sur deux profils pris chacun dans les séries d'Atwood, Lucedale et Savannah. Atwood s'est formé principalement dans un loess épais sur des sédiments de plaine côtière, Lucedale montre clairement l'influence du loess jusqu'à une profondeur de 10 pouces et un mélange possible plus profondément, tandis que Savannah indique une légère présence de loess jusqu'à une profondeur de 20 pouces. Atwood et Lucedale sont tous deux des sols bien drainés, tandis que Savannah n'est que modérément bien drainé et contient un fragipan.

La minéralogie de l'argile grossière (2–0,2 μm) apparaît comme le meilleur caractère diagnostique dans la différenciation génétique des sols. Dans cette fraction de l'argile, la montmorillonite est très abondante dans Atwood, diminue dans Lucedale et n'existe seulement qu'à l'état de trace dans Savannah. Dans les sols d'Atwood et Lucedale, on trouve très peu de montmorillonite à une profondeur de 35 pouces, là où l'influence de la plaine côtière prédomine d'une façon apparente. Simultanément, les minéraux intergrades alumineux vermiculite-chlorite sont peu abondants dans Atwood, augmentent dans Lucedale et se rencontrent aux plus fortes teneurs dans Savannah.

Parallèlement à ces variations dans la minéralogie on observe des changements correspondants dans les propriétés chimiques. Quoiqu'on n'ait pas trouvé de différences significatives dans les teneurs en calcium et magnésium entre les sols d'Atwood et de Lucedale, Atwood et Lucedale sont tous deux beaucoup plus riches en calcium et magnésium échangeables que Savannah. Le pH et la saturation en base des sols augmentent dans l'ordre Savannah, Lucedale et Atwood.

Kurzreferat—Es wurde festgestellt, daß die chemischen und mineralogischen Eigenschaften von 6 Böden, von denen man früher annahm, daß sie aus Sedimenten der Küstenebene gebildet worden waren, deutlich durch dünne Lößauflagen und Beimengungen beeinflusst sind. Die Studie schließt je zwei Profile der Atwood-, Lucedale- und Savannah-Serie ein. Atwood wurde vorwiegend in mächtigem Löß über Küstenebenen-Sedimenten gebildet, Lucedale zeigte deutlichen Lößeinfluß bis zu einer Tiefe von 25 cm und mögliche Beimischungen bis zu größerer Tiefe, während Savannah das Vorliegen von wenig Löß bis zu einer Tiefe von 50 cm erkennen ließ. Sowohl die Atwood- als auch die Lucedaleböden sind gut wasserdurchlässig, während Savannah mäßige Durchlässigkeit und einen tonigen Verdichtungshorizont besitzt.

Die mineralogische Zusammensetzung des Grobtons (2–0,2 μm) scheint das wichtigste diagnostische Merkmal für den Nachweis einer genetischen Differenzierung zwischen den Böden zu sein. Montmorillonit war in dieser Tonfraktion am reichlichsten in Atwood, vermindert in Lucedale und nur in Spuren in Savannah enthalten. In den Atwood- und Lucedaleböden wurde sehr wenig Montmorillonit in Tiefen von 90 cm gefunden, wo der Einfluß der Sedimente der Küstenebene offenbar vorherrscht. Im Gegensatz hierzu waren aluminiumhaltige Vermiculit-Chlorit-Übergangsminerale am wenigsten häufig in Atwood, zunehmend in Lucedale und in größten Mengen in Savannah vertreten.

Diese Veränderungen in der mineralogischen Zusammensetzung waren von entsprechenden Veränderungen in den chemischen Eigenschaften begleitet. Obwohl keine konsistenten Unterschiede im Calcium- und Magnesiumgehalt zwischen Atwood- und Lucedaleböden gefunden wurden, enthielten sowohl Atwood als auch Lucedale viel mehr austauschbares Calcium und Magnesium als Savannah. pH-Werte und Basensättigung der Böden stiegen in der Reihenfolge Savannah, Lucedale und Atwood an.

Резюме — Нашли, что на химические и минералогические свойства шести почвенных слоев, которые ранее предполагалось образовались на прибрежных равнинах из осадков, сильно повлияли вышележащие пласты и примеси лёсса. Исследовались по два профиля атвудской, люцидельской и саванной почв. Атвудская почва главным образом образовалась в глубоком лёссе поверх осадков прибрежных равнин, люцидельская почва ясно проявляла влияние лёсса на глубину 10 дюймов и, возможно, примеси еще на большую глубину, в то время как в почве саванны на глубине 20 дюймов нашли только малое количество лёсса. Атвудская и люцидельская почвы хорошо дренируются, а почва саванны только умеренно и она содержит фраджипан.

Минералогию крупнокомковатой глины (2–0,2 μm) было легче всего распознать и она указала на генетическую разницу почв. Больше всего монтмориллонита нашли в атвудской фракции глины, менее в люцидельской, а во фракции саванны только следы его. В атвудской и люцидельской почвах на глубине 35 дюймов нашли очень малое количество монтмориллонита, здесь, очевидно, преобладает влияние прибрежных равнин. И наоборот, в атвудской почве нашли меньше всего глиноземных, вермикулитно-хлористых минералов, немного больше в люцидельской и самое большое количество в почве саванны.

Эти минералогические изменения сопровождались изменениями химических свойств, хотя, в атвудской и люцидельской почвах не нашли соответствующих изменений в содержании кальция и магния, но все таки содержание обменного кальция и магния в них было выше, чем в почве саванны.