Psammaquents, Sulphihemists, and Sulfaquents were found in the tidal marshes of Hernando (Gulf Coast) and Duval (Atlantic Coast) counties, in Florida. They were saline and near neutral in pH and, with the exception of the Psammaquents, contained higher levels of S (2.66–5.19%). Hernando County soils were shallow over limestone and much sandier than those in east Florida. Duval County soil clays were primarily montmorillonite, mica, and kaolinite but Hernando County soil clays were mostly vermiculite-chlorite intergrade and kaolinite-metahalloysite. Except for one of the Psammaquents, the soils contained relatively high levels of organic matter (7.8–28.9% organic C) and extractable bases. Juncus roemerianus Scheele is the principal plant in these marshes. The bulk density of the organic soil layers ranged from 0.13 to 0.36 g/cm², whereas that of the clayey layers was 0.16 to 0.25 g/cm².

Additional Index Words: soil classification, histosols, sulfidic materials, aequents, soil morphology.

LITTORAL ZONES of the Western Hemisphere have traditionally been neglected by pedologists for various reasons. They are generally inaccessible, inhospitable, and of minimal agricultural value. Tidal marsh and swamp areas have generally been relegated for use as a wildlife habitat and recreational areas (Rutledge, 1973). In a recent southern regional publication (Buol, 1973) these areas are included in the "Duneland-Tidal Swamp" association of "land types". In detailed soil surveys of Florida coastal areas, such as Pinellas County (Vanatta et al. 1972), tidal
areas are separated into two land types referred to as "Tidal Marsh" and "Tidal Swamp." Tidal marshes and associated estuaries are now becoming more attractive for many kinds of economic development; however, the value of the marsh in its relatively undisturbed state has often been overlooked. It is essential in the propagation and development of many marine organisms (Heald and Odum, 1969) providing both food and a relatively safe habitat. Gosselink et al. (1973) estimated the value of Spartina alterniflora marshes in Georgia for fisheries to be in excess of $247/ha per year ($2,000/acre capitalized at 5%). The marsh provides other functions as well, such as erosion protection and habitat for migratory birds.

As population pressures increase, tidal areas are assuming greater importance as a land resource. More detailed investigations are needed to provide a base for determining their best use. Thus, the purpose of this research was to characterize and classify the important tidal marsh soils in Duval (Atlantic Coast) and Hernando (Gulf Coast) counties of Florida.

DESCRIPTION OF THE STUDY AREA

The location of Hernando and Duval counties is shown in Fig. 1. There are approximately 4,675 ha of tidal marsh in Hernando and 20,250 ha in Duval County. Considerable filling has taken place in the marshes of Duval County (Jacksonville). Further, an estimated 337 ha have been destroyed by recent housing developments in Hernando County.

The climate of the study area is humid and temperate to subtropical. Mean annual precipitation in Duval County is 135.6 cm and 147.3 cm in Hernando County (U.S. Dep. of Commerce, 1972). The mean annual temperature is 20.8°C in Duval County and 22.2°C in Hernando with a range of mean monthly temperatures of 14.2°C to 28.1°C in Duval and 16.2°C to 27.3°C in Hernando County. The predominate vegetation of the tidal marshes of Florida is Juncus roemerianus Scheele. Spartina alterniflora Loisel commonly occurs at lower elevations and Distichlis spicata L. Greene in higher elevations.

Slope in tidal marshes is < 1% except at the boundaries between marshes and the sea and marshes and the uplands where slopes of 3 to 5% or greater may occur. A well-developed meandering stream system exists which permits rapid ingress and egress of tidal waters. Twice daily inundation of the marsh is normal. Mean tidal range in Duval County (Mayport) is 1.4 m, whereas in Hernando County (Bayport) it is only 0.7 m (U.S. Dep. of Commerce, 1974).

Most tidal marshes in Florida are 1 to 2 km in width; however, some of the marshes along the St. John's and Nassau rivers in Duval County are about 4 km wide. The soils in the Hernando County marshes are developing in recent sediments < 1 m in thickness over Suwannee Limestone and the Crystal River Formation (Puri and Vernon, 1964). The marsh sediments in Duval County are Recent and Pleistocene and are of considerable thickness.

INVESTIGATION PROCEDURES

Field Procedures—Sites were selected and pedons described in cooperation with the Soil Conservation Service (USDA) party chiefs in charge of progressive soil surveys in Hernando and Duval counties. Several transects in each county were conducted with an "all-terrain" vehicle and the major soils were described and sampled following procedures outlined in the Soil Survey Manual (1951).

Chemical Procedures—The following methods were used for chemical analyses: pH in water by a glass electrode (8Clα);² organic carbon by wet combustion (6Alα);² extractable bases obtained with ammonium acetate (5Blα)² and determined by flame photometry (K and Na) and atomic absorption spectrometry (Ca and Mg); conductivity from a saturation extract (8A1α);² total nitrogen by kjeldahl digestion (6Blα);² total S was determined with ammonium acetate (5Blα)² and determined by titrimetric method (6Ele).³ Total S was determined using a Leco S analyzer (Model 532) employing antimony and sodium azide to eliminate interferences (Tiedman and Anderson 1971).

Physical Procedures—Undisturbed core samples (5.4 by 3.0 cm) were placed in Tempe pressure cells, saturated, and then extracted sequentially at pressures of 30, 60, 100, 150, 200, and 345 millibars. Water contents were determined from the weights of the cells at each equilibrium pressure and the oven-dry weights of the soil core. Only the 60 millibar (0.06 bars) water contents are reported in this paper. Before drying, the cores were resaturated for determination of saturated hydraulic conductivity. After oven drying, the samples were ground to pass a 2-mm sieve and the 15-bar water retention was determined. Particle-size distribution was by the hydrometer method (Bouyoucos, 1962). Field moisture content was determined on a subsample of the bulk sample. Volumetric field water percentage was derived from bulk density values determined on the core samples.

Mineralogical Procedures—Mineralogy of the clay (< 2µm) fraction was by X-ray diffraction procedure (7A2d)³ with a General Electric SRD-7 instrument using Ni-filtered CuK radiation.

RESULTS AND DISCUSSION

Morphological Properties

The marsh soils of Hernando County are underlain by limestone within 1 m. The northern Florida Atlantic coastal soils (Duval County) are developing in a much thicker regolith (Table 1). Pedogenic horizonation in the mineral materials is generally negligible except for the presence of an incipient B horizon in profile 27-2 and the melanized Al horizon of profile 27-1. All of the organic soil layers were classified as sapric in the field. A 17 cm-thick surface layer high in calcium carbonate was noted in profile 27-2.

³Symbols in parentheses indicate the reference to the method in Soil Survey Investigations Report No. 1, revised (Soil Survey Staff, 1972).
Chemical Properties

The marsh soils were near neutral or alkaline in reaction under field conditions except the Oa2 horizon (pH 5.4) of profile 16-1 in Duval County (Table 2). Maximum alkalinity (pH 8.2) occurred in the carbonatic overburden of profile 27-2. The calcium carbonate equivalent of these horizons was 57.5% in the C1 and 47.7% in the C2. The 11Alb and 11Bb horizons of this pedon had CaCO₃ equivalents of 13.1% and 1.4%, respectively. With the exception of profile 27-2 all soils became more acid upon drying, indicating the oxidation of S compounds. Extreme changes in pH were usually related to high levels of S. Maximum field moist pH values occurred at the surface in Hernando County soils. With depth the soils became more acid before becoming more alkaline as the underlying limestone was approached. Duval County soils tended to become more alkaline with depth from the surface.

Electrical conductivity values indicated that all of the marsh soils were highly saline. Conductivity ranged from 22.6 mmhos/cm at the surface of profile 16-2 in Duval County to 61.4 in the Oa2 horizon of profile 27-5 in Hernando County.

The sum of extractable bases was usually highest in the surface horizons and decreased with depth (Table 2). This trend was related to organic C distribution with depth. Calcium was the predominant cation in the Hernando County soils. Magnesium predominated in the Duval County soils. The ratio of extractable Na + Mg to extractable bases was considerably higher (50-75%) in Duval County soils than in the Hernando County soils (generally < 50%).

Both C and N tended to concentrate in the surface horizons (Table 2). Increasing C/N ratios with depth reflected greater microbial activity of the surface horizons and deni-
All sapric materials and clayey 11C horizons contained sufficient S to qualify as sulfidic (0.75%). Profiles 27-1 and 27-2 in addition to the coarse-textured 11C2 horizon of profile 16-1 all had total S contents below 0.75% (Table 1). Distribution of total S with depth shows that maxima generally occurred at 35–55 cm. Total S has been found to be highly correlated with organic C (R=0.80) in some Iowa soils by Tabatabai and Bremner (1972), but this relationship is not obvious in these marsh soils. Except for profile no. 27-2, C/S ratios decrease with depth showing a relative enrichment of S suggesting the translocation of S or the effect of reducing conditions in the lower zones of more permanent saturation.

**Physical Properties**

Particle size distribution data (Table 3) show that the mineral portions of these tidal marsh soils are quite stratified. The Duval County soils contained 4 to 10 times more mineral portions of these tidal marsh soils are quite stratified. The Duval County soils contained 4 to 10 times more mineral portions of these tidal marsh soils are quite stratified. The Duval County soils contained 4 to 10 times more mineral portions of these tidal marsh soils are quite stratified. The Duval County soils contained 4 to 10 times more mineral portions of these tidal marsh soils are quite stratified. The Duval County soils contained 4 to 10 times more mineral portions of these tidal marsh soils are quite stratified. The Duval County soils contained 4 to 10 times more mineral portions of these tidal marsh soils are quite stratified. The Duval County soils contained 4 to 10 times more mineral portions of these tidal marsh soils are quite stratified. 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Table 4—Semiquantitative estimation of clay minerals in selected horizons of tidal marsh soils from Hernando and Duval counties, Florida.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Clay species*</th>
</tr>
</thead>
<tbody>
<tr>
<td>HERNANDO COUNTY</td>
<td></td>
</tr>
<tr>
<td>A11</td>
<td>S73Fla-27-1</td>
</tr>
<tr>
<td>A12</td>
<td></td>
</tr>
<tr>
<td>AC1</td>
<td>S73Fla-27-2</td>
</tr>
<tr>
<td>CI</td>
<td></td>
</tr>
<tr>
<td>11Bb</td>
<td></td>
</tr>
<tr>
<td>DUVAL COUNTY</td>
<td></td>
</tr>
<tr>
<td>11C</td>
<td>S74Fla-16-1</td>
</tr>
<tr>
<td>11C1</td>
<td></td>
</tr>
<tr>
<td>11C2</td>
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</tr>
</tbody>
</table>

* V—Aluminum interlayered vermiculite, K—Kaolinite and metahalloysite, M—Montmorillonite, mica mixture, Mi—Mica, Q—Quartz, Ca—Calcite. 1 = >40%, 2 = 10-40%, 3 = <10%.

In contrast, the Duval marsh soils clays were composed mostly of kaolinite, montmorillonite, and mica. The clay mineral composition of the marsh soils is similar to that of the surrounding upland soils and sediments on both coasts.

Classification of the Soils

Diagnostic horizons and features and classification of the soils at the family level are as follows. Pedon 27-1 is mineral throughout with an n-value that is too high to qualify as a mollic epipedon. The texture is loamy fine sand from 20-cm depth to a paralithic contract and total S is too low to qualify any of the horizons as sulfidic. Within the context of the present classification system (Soil Survey Staff, 1975) it is classified as a siliceous, hyperthermic Typic Psammaquent. Classification of pedon 27-2 is based on the properties of the soil underlying the 17-cm-thick carbonatic layer. It has an ochric epipedon, the depth to lithic contact is 25 cm, and the B horizon is sandy. It is classified as a siliceous, hyperthermic Lithic Psammaquent. Pedon 27-5 is sapric throughout to a paralithic contact at 74 cm and all horizons are sulfidic. Within the context of the present classification system it is classified as a euic, hyperthermic Typic Sulphihemist, although lithic subgroups are recognized in other Hemists. Pedon 16-1 has a histic epipedon underlain by mineral material at 25 cm. The histic epipedon and clayey 11C1 horizon are both sulfidic. It is classified as a very-fine, mixed, nonacid, thermic Typic Sulfaquent. Pedon 16-2 has a 40-cm-thick sapric horizon and is strongly sulfidic throughout. It is classified as a euic, thermic Typic Sulphihemist.

The classification of these soils suggest that further refinement in certain of the taxa is needed in order to emphasize some important properties of these soils at a taxonomic level above that of the series. There is a need for recognition of the high level of soluble salts in all of the marsh soils. The thick clayey mineral layer with the high (2-3) n-values in profile 16-2 should be recognized at the subgroup level as an intergrade towards the Hydraulents.

Other Considerations

There was only a slight change in slope between the marsh and the adjoining upland soils in Hernando County, but there was commonly an abrupt slope change between these landscape positions in Duval County. The marsh appears to be encroaching on the upland in Hernando County, but this is not evident in Duval County. The Lithic Psammaquent (27-2) in Hernando County which is overlain by carbonatic material provides evidence for a 50–100 cm higher sea level stand.

The marsh soils in both counties supported luxurious stands of vegetation, predominately, Juncus roemerianus which provides much of the essential detritus for many marine organisms. These soils also have a high capacity for adsorbing nutrients from the tidal waters. The high level of S found in most of the soils would cause serious problems if they were drained (Fleming and Alexander, 1961). The low bulk density and high water content of all soils except the Lithic Psammaquent suggest the low mechanical bearing capacity of these soils and the excessive shrinking which would occur upon draining.

ACKNOWLEDGMENTS

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