USE OF MODELS BASED ON MODERN PEAT DEPOSITS TO PREDICT THE DISTRIBUTION OF MINERAL MATTER IN COALS

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Numerous models have been proposed to define the depositional settings under which coals might have formed in the past. The purpose of these models is to aid in predicting the compositional and mining characteristics of these coals. Our studies of modern peat deposits from Florida, Georgia, South Carolina, North Carolina, and Louisiana are providing us with data with which to both refine existing models and also to develop new models. This paper focuses on one aspect of our studies, the distribution of mineral matter in peats. Since most of our studies have been of intrashoreline, coastal plain peat deposits (e.g., Snuggedy Swamp, Okefenokee Swamp), our model for this type of setting is more precise than for any other type and, consequently, more readily used for predictive purposes in the ancient.

INTRODUCTION

Various depositional models have been proposed to explain the variability and predict the economic characteristics of coal seams (FERM et al., 1971; HORNE et al., 1978; ROEHLER, 1976; COHEN and STAUB, 1977; COHEN, in press). These models can be used to predict a variety of quality parameters, one of which is mineral matter distribution.

Our studies of peat deposits of the southeastern United States have enabled us to develop several different coastal plain models. One model which we have found to have particularly wide applicability to ancient coals is the "back-barrier" or "intrashoreline" model (COHEN, in press). Although this is only one of several depositional models that we have constructed, we have the greatest amount of data to support this model. Thus, it will be used in this paper as an example of the predictive capabilities of such models.

It should be made clear that we are not suggesting that this model be used to explain all coal seams, only that this model has been found to adequately explain and predict the characteristics of certain coal seams.

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It is important that any relatively unstudied coal seam be investigated with many potential models in mind. Then, as preliminary data are generated, various models can be matched with that data to see which one best fits predicted conditions.

INTRASHORELINE COAL-FORMING MODEL

Numerous papers have been published in the last several years concerning the presence in coal-bearing strata of quartz-rich arenites (orthoquartzites), which have been interpreted as beach-barrier deposits (HOBDAY, 1974; HORNE et al., 1978; MASTERS, 1966; ROEHLER, 1976). However, the model that is usually shown depicts a coal-forming environment directly behind an active coastal beach-barrier deposit. Although many mineable coals are found in juxtaposition with barrier deposits, such as the Beckley Seam of West Virginia, the true back-barrier environment (i.e., the salt marsh or brackish lagoonal environment) has been found in the modern to be a very poor one to produce anything more than thin lenses of high sulfur, high ash coal or carbonaceous shale (ALLEN, 1978). On the other hand, the Okefenokee Swamp peats would, if buried, produce a high-quality, low-sulfur coal seam behind an orthoquartzitic barrier facies. However, the barrier and underlying lagoonal salt marsh sediments, where still present, are many thousands of years older than the peat. This disconformity is very subtle and would probably not be noticeable in the rock record. This observation suggests the possibility that this phenomenon might have occurred in the geologic past and that all fossil "back-barrier" coals may not have formed directly behind active shorelines. Furthermore, other than its large size, the Okefenokee Swamp setting is not really unusual in modern coastal plains. The presence of "stranded" barrier features is typical of nearly all of the Atlantic Coastal Plain from New Jersey to Florida. Each barrier has a relatively flat, relatively impermeable (former) salt marsh surface behind it and many of these surfaces contain peat deposits. It appears that when, and if, hydrologic and climatic conditions become favorable for peat deposition, these surfaces are ideal places for it to start. Peat deposition might also start somewhat contemporaneously in many of these sites but at different elevations (COHEN, in press).

Because of these observations, we felt it would be useful to compare the Okefenokee type deposit with some contemporaneous peat deposits occurring at

various lower elevations toward the present coastline. Figure 1 illustrates the three types of environments encountered behind beach-barrier features in the temperate region of the Atlantic Coastal Plain. The Okefenokee Swamp (Type III) illustrates the totally inland type with no marine influence (Fig. 1a); the Snuggedy Swamp of South Carolina (Type II) is typical of a marginal marine or upper estuarine setting (Fig. 1b); and a lagoonal-salt marsh behind or close to the marine environment is illustrated as Type I (Fig. 1c). Figure 2 shows the three types of depositional environments in their relative positions with respect to the ocean. Note that grouping these three types of intrashoreline settings into one model allows one to readily compare and contrast the occurrence, distribution, and composition of the mineral matter between types. Note also that, in the ancient, only one of these types might be present, or two might occur, or all three might occur. Furthermore, there is a tendency in relatively gently dipping coastal plain areas for shorelines to migrate back and forth with only slight changes in sea level or subsidence (or emergence) of the land. Thus, over many thousands of years, "back-barrier" peat deposits may become stacked one upon the other. For example, RICH (1979) noted the occurrence of an older peat deposit trapped beneath the barrier sands of Trail Ridge (which borders the Okefenokee Swamp on the east). Based on Rich's data (pollen analysis) and our model, we would interpret this peat to be an "Intrashoreline Type II" deposit. This deposit formed under different conditions than those which formed the Okefenokee Peats (Type III).

The stacking of orthoquartzitic sandstones (barrier deposits) and associated coals must have been a common phenomenon in the ancient, as indicated by numerous coal studies (e.g., ROEHLER, 1976; HOBDAY and HORNE, 1977; HOBDAY, 1974). An intrashoreline model, as we have proposed in this paper, can be of great use in distinguishing between types of back-barrier coals. For instance, it can be used to develop a sampling plan and also to determine which parameters would need to be measured in order to establish which subtype you might be observing in the ancient. Once the subtype has been established (by measuring only a few parameters), most other parameters should be predictable. Such relatively simple parameters as total sulfur (or forms of sulfur) in a coal seam cannot be predicted based solely on an interpretation that the coal is "back-barrier," as has been done often in the past. As indicated by our model, a back-barrier coal can range in sulfur

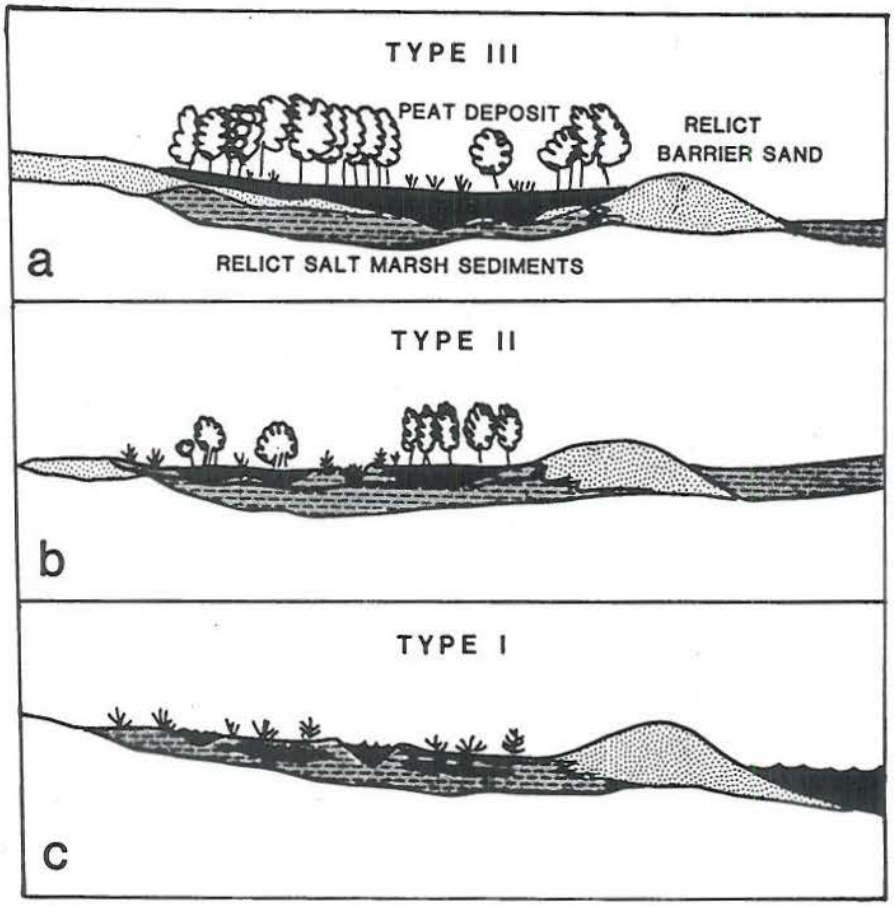

Fig. 1. Three types of back-barrier depositional settings on the Atlantic Coastal Plain of North America.

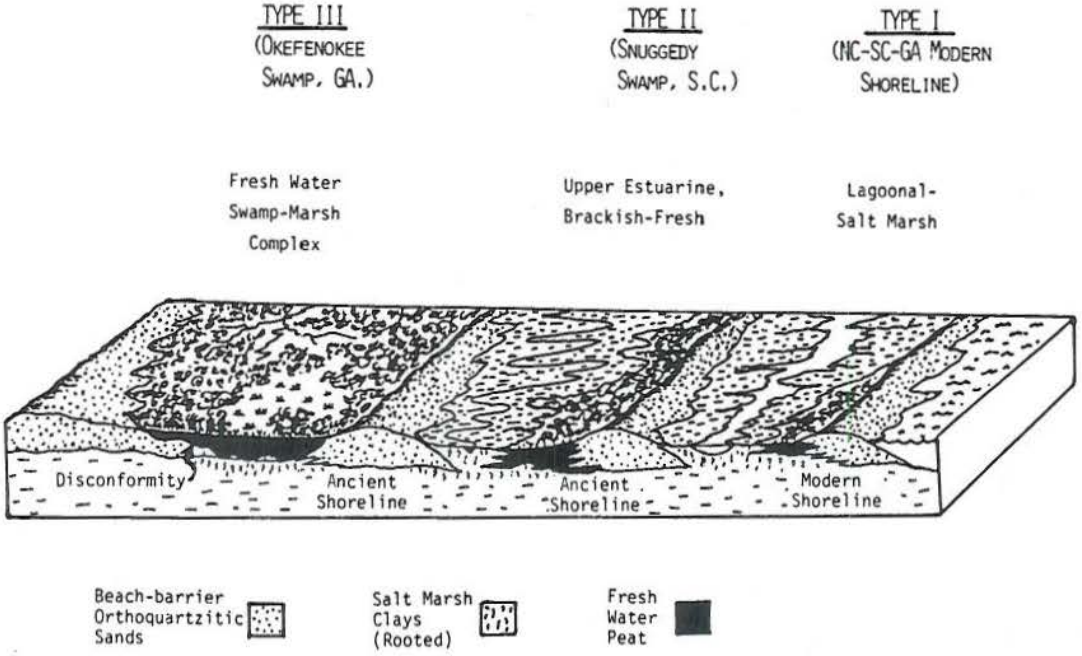

Fig. 2. Schematic diagram representing shoreline-related peat-forming environments (warm temperature climate) (after COHEN, in press).

content anywhere from low-sulfur content to high-sulfur content depending primarily on its position with respect to the marine environment during peat deposition and secondarily upon the lithology of the overlying sediments (COHEN et al., 1971; 1983; RAYMOND and DAVIES, 1979).

Table 1 gives some characteristics of the mineral matter in each of the subtypes in a temperate climatic setting. Additional characteristics of these deposits (such as, petrographic composition, geometry, and effects of climate) are given in COHEN (in press). Note that inorganic "splits" in the peat deposits can be of two types: (1) continuous relatively uniform splits caused by changes in sea level (eustatic), and (2) wedge-shaped splits which thicken toward stream channels (splays). An additional potential type of split, which does not occur in Atlantic Coastal Plain peats and thus is not shown in our table, is that produced by volcanic ash falls. This type can occur in coastal plain areas having nearby active volcanism, and would result in a type of split which would be relatively continuous and uniform.

Splays can be of two types, crevasse splays and fire splays. The geometry and characteristics of these types of splays are described in detail in STAUB and COHEN (1979). Note that crevasse splays increase in importance from Type III toward Type I; whereas, fire splays are most common in Type II deposits and are rare in Types III and I. The mineralogical composition of the splays in intrashoreline deposits varies from freshwater, quartz-rich silts and sands in Type III to marine-dominated clays and silts in Type I deposits.

The disconformity between the underlying deposit, seat earth, and the overlying peat becomes greater from Type I toward Type III. The composition of the seat earth tends to change from a clay-rich deposit (underclay) to a quartz-rich, sandy, or silty material (gannister) from Type I toward Type III. Although not shown in the table, the pH of the peats decreases from Type I to Type III; consequently, clays which occur beneath the peat (underclays) or as splits (splays or tonsteins) tend to be enriched in kaolinite in Type II and Type III deposits (STAUB and COHEN, 1978).

In general, the mineral matter in Type III deposits is authigenically dominated; whereas Types II and I are detritally dominated. The grain size of detrital minerals tends to increase from Type I toward Type III. The authigenic mineral matter in Type III deposits is primarily biogenic silica (sponge spicules and diatoms) except toward the base and periphery of the

TABLE 1. Temperate zone intrashoreline model

PARAMETER	TYPE III	TYPE II	TYPE I
A. Splits			
1. Types			
a. Eustatic (Regional)	Possible; continuous and relatively uniform in thickness over wide area	Common; ditto Type III	Most common; ditto Type III
b. Splays			
1) Crevasse	Rare; wedge-shaped; ⊥ channels; small in geographic extent	Common; ditto Type III	Most common; ditto Type III
2) Fire	Rare; wedge-shaped; more tapering; not nec. ⊥ channels; larger geog. extent; basal inertinite layer	Common; ditto Type III	Rare; ditto Type III
2. Composition	Quartz-rich silts and sands with some heavy minerals.	Clay-dominated (fluvial and marine); some quartz-rich silts.	Marine-dominated clays and silts.
B. Seat Earths	Disconformity greatest between coal and seat earth; gannisters (qtz. sands) more likely than underclays; kaolinite enrichment common.	Disconformity less likely or absent; underclays more common than gannisters; kaolinite enrichment common.	No disconformity; underclays most common; kaolinite enrichment least common
C. Mineral Content of Peat			
1. General	Low; grain size (detrital) coarsest of three types; clays, if present, most likely kaolinite-enriched.	High toward channels and low toward the barriers; grain size intermediate; kaolinite-rich clay lenses common.	Highest; grain size finest; kaolinization of clays likely.
2. Types	Dominated by biogenic silica; basal and peripheral quartz with some clays.	Dominated by clay minerals, quartz, sulfides and sulfates.	Dominanted by clay minerals, quartz, sulfides, sulfates and biogenic silica and carbonates.
3. Genesis	Authigenic-dominated	Detrital-dominated	Detrital-dominated
D. Sulfur	Low (primarily organic); no pyrite	High near base and channels, low elsewhere; where high, pyritic forms also high; beneath splays pyrite higher.	Generally high to moderate throughout

deposits, where detrital quartz and clays increase. Total sulfur is low and composed primarily of organic sulfur. Type II deposits are dominated by clay minerals, quartz, and sulfides and sulfates. Total sulfur and pyrite tend to increase toward channels and beneath splay deposits. These increases reflect marine influences. On the other hand, Type I peats tend to have the highest amounts of mineral matter. Marine-derived clay minerals dominate, with quartz sand and silt (and some heavy minerals) being introduced by washovers and splays. Marine biogenic silica and carbonates, both authigenic and detrital (such as marine shell fragments, sponge spicules, and other skeletal remains) may be associated with Type I deposits.

CONCLUSIONS

Data from studies of modern peat deposits on the Atlantic Coastal Plain of North America have been used to develop an intrashoreline (or back-barrier) model that can be subdivided into three subtypes. Although all deposits have seaward-bounding orthoquartzitic, beach-barrier features, each subtype has a distinctly different inorganic complement. Type III (the Okefenokee Swamp type) deposits are dominated by authigenic-biogenic silica toward the center (see ANDREJKO et al., 1983) with some detrital quartz sand and silt and kaolinitic clays toward the base. Along the periphery of the swamp and toward the beach-barrier features, quartz sand, silt, and some heavy minerals predominate. The Type III peats are totally freshwater and are low in total sulfur. Type II (Snuggedy Swamp type) deposits are characterized by a combination of marine and freshwater sediments. Kaolinite-rich crevasse and fire splays are common, with pyrite and total sulfur tending to increase toward stream channels and beneath these splays. Type I peat deposits tend to be the thinnest, highest in detrital mineral matter, and highest in total and pyritic sulfur. Biogenic marine skeletal fragments (calcareous and siliceous) may also be associated with these peats.

The three-part intrashoreline model proposed herein has been found to be useful not only in understanding the depositional history of "back-barrier" coals but also in predicting the compositional characteristics of these coals.

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