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SL229

Landscape Diversity: Multiple-Use Landscapes for Reclaimed Phosphatic Clay Areas[1]

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Intent

The land form heterogeneity typical of the phosphatic clay areas of Central Florida's phosphate mining district provides a unique opportunity for a multitude of land uses within a relatively small area. This publication explores the advantages and challenges of using reclaimed phosphatic clay areas for agricultural operations while simultaneously restoring lost wetland functions, improving water quality and water use efficiency, and retaining areas valuable to wildlife. With planning, the resources within these land-forms will be assets to the local economy and will provide beneficial environmental services to surrounding communities. This article is written as a concept paper, which integrates information learned about phosphatic clay (for example, *Phosphatic Clay for Agricultural Uses: Bibliography*, http://edis.ifas.ufl.edu/ss444, last accessed July 16, 2011).

A variety of waste clay and sand disposal methodologies has been used since phosphate mining began in Central Florida. Each mine contains examples of these variations, depending on mine age, location, physiography, and operational parameters. The basic tenets stated in this paper for **clay settling areas (CSA)** studied in the Polk County Mined Lands Agricultural Demonstration Project are valid for all methodologies. Further observations, with respect to mine age and methodologies and in the context of enhanced regional landscape diversity, will be stated in subsequent papers.

Description of Phosphatic Clay Areas

1. Phosphatic clay is one of the by-products of phosphate mining, and CSAs typically constitute more than 40% of the landscape after the completion of mining and reclamation.

a) The phosphatic clay material is mostly in the clay-size fraction, usually containing both Montmorillonite and Palygorskite with some phosphorites.

i) This combination of clays, which are **Ca and Mg saturated**, provides flocculated, highly fertile clay with manageable tillage and high water holding capacity.

ii) Hydraulic conductivity of phosphatic clay is in the range of 10^{-7} cm/hr, which means that water within the **clay drains slowly**.

iii) The capillary water movement through phosphatic clay is considerable, both laterally and vertically; however,

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the movement is slow because of reduced hydraulic conductivity.

iv) When dried, **cracks** as wide as 10 cm (4 inches) will form at the surface, extending downward more than 30 cm (1 foot) due to the **shrink/swell properties** of the **montmorillonite** clay.

(a) This cracking will cause:

(*i*) **Vertical mixing**, often moving organic matter deeper into the phosphatic clay profile;

(*ii*) Ready **entrapment of rainfall**, often capturing as much as 2.5 cm (1 inch) without appreciable runoff; and

(*iii*) Possible **root damage** for some plants.

b) Major limitations of phosphatic clay include slow drainage, high shrink/swell characteristics, stickiness, problems with trafficability in wet conditions, instability for construction of structures, and nitrogen deficiency for crop production.

2. The CSAs, used to recycle water from the hydraulically deposited phosphatic clay, are often previously mined and may contain other materials such as **sand tailings** (sand removed with the clay during the extraction of the phosphate ore) and **overburden** (the original pre-mining soil).

a) There is considerable diversity of materials both within and among phosphatic clay settling areas.

3. The landscape form of the **containment area** (Figure 1) before the introduction of phosphatic clay greatly influences the reclaimed phosphatic clay surface relief.

a) The **depth of phosphatic clay** will vary with the underlying terrain (Figure 2) and the method of deposition. Where a valley exists in the floor of the CSA, the phosphatic clay deposit will be the deepest.

4. As the phosphatic clay dewaters during the reclamation process (i.e., active use for mining purposes has ceased), the phosphatic clay undergoes **subsidence** or more appropriately **differential settling**. Dewatering starts with the slurry left after hydraulic deposition, which contains less than 5% solids. After reclamation, most of the water has been removed and the dewatered surface is greater than 50% solids and safe for machinery and humans.

a) The most differential settling will occur where clay deposits are the deepest. It is a common observation in reclaimed CSAs that lower elevation post-reclamation landscape surfaces correspond geographically to the locations of valleys between rows of mining spoils that existed before deposition of the clays, and higher elevation post-reclamation landscape surfaces correspond geographically to the locations of the rows of mining spoil that existed before deposition of the clays. As a result, areas that correspond to spoil rows generally have better drainage, and areas in the valleys are often saturated or inundated with water during much of the year.

i) The effects of differential settling on the phosphatic clay surface can be observed in as few as 4 or 5 years after reclamation. The rate of differential settling is usually the most dramatic during the first 5–10 years. After that time, differential settling does continue, though usually at a much slower rate. Eventually, annual differences in elevation become negligible.

ii) Differential settling will continue until the **bulk density** of the phosphatic clay increases sufficiently to support the weight of the phosphatic clay above. Typically, reclaimed phosphatic clay has a bulk density from 0.6 to 1.2 g cm^{-3}. This wide range is a reflection of both the variability of its composition and the stage of differential settling.

(*a*) In a 3-year trial on an unmined CSA involving selected rates of biosolids, the phosphatic clay bulk density remained at 0.9 g cm^{-3}. However, the depth of the phosphatic clay was only 1 meter.

(*b*) **Macrobeds**, drainage landforms for intensive use of phosphatic clay, were developed at several phosphatic clay sites by the primary author in the mid-1990s. Differential settling eventually destroyed the macrobeds within 5–8 years depending upon the depth of the clay. At these sites, clay depths varied from 1 meter to more than 20 meters.

(*i*) The added weight of phosphatic clay along the small ridge of the macrobed may actually exacerbate differential settling, especially if the crown of the macrobed does not coincide with the underlying CSA floor.

5. As clay is deposited, more coarse-grained materials fall out close to the location of initial introduction of the material into the settling area; finer-textured materials remain in the slurry throughout longer distances. The result is gentle relief from the location(s) where materials are introduced to the area where water is decanted from the settling basin.

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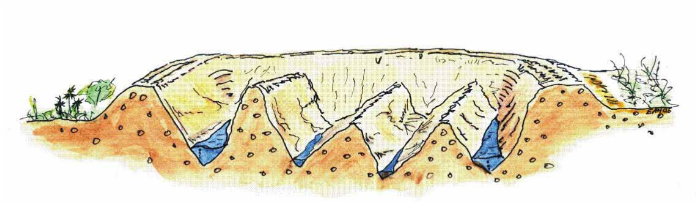

Figure 1. This concept drawing shows the landscape that will be used for the deposition of phosphatic clay, the so-called containment area. Note the windrows of materials and the formation of a berm around the perimeter. The shape of this basin will affect the shape of the phosphatic clay after reclamation and differential settling.
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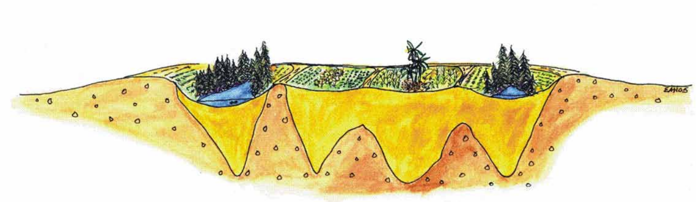

Figure 2. The same site is shown after clay deposition, reclamation, and several years into the differential settling process. Note that the berm has been reshaped and managers have used the multiple-use landscape approach immediately after reclamation of the surface. Tree planting and location of access roads are based upon underlying strata. Deeper zones of phosphatic clay have been set aside for water and wetlands. Filter strips surround these low areas. An assortment of crops (sod, energy crops, forages, native grasses for seed/transplanting) is positioned in the landscape based upon slope and drainage considerations. In this concept drawing, differential settling and original underlying strata have occurred at different rates. Note that the underlying strata is used as a road (left side of drawing and to the immediate right of trees) since this material extends to the surface. The phosphatic clay to the right of that road contains row crops and a swale in the middle for drainage and water quality considerations. Steeper land (far right on the side of the residual berm) is in grasses for stability on the slope.
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Identification of Target Post-reclamation Land Uses for Phosphatic Clay Disposal Areas

1. Creation of multiple-use landscapes will provide opportunities for various land uses following reclamation, such as these examples:

a) High-value fruit and vegetable crops

i) Yields and quality of many crops grown on phosphatic clays are high. Also, these crops often require less irrigation and lower inputs of fertilizer than those produced in other areas of Florida.

b) Pastures for grazing, hay and silage production, or sod farming

c) Biomass production

i) Short Rotation Woody Crops (SRWC) for production of biomass have been successfully produced on reclaimed phosphatic clay soils.

ii) Other biomass crops, such as switchgrass, sugarcane, or corn, could also be produced in some areas.

d) Silviculture for multiple forest products

i) Lumber for pallets, stakes, and produce-transfer boxes

ii) Pulp-chip wood

iii) Landscape mulch

e) Wetlands and wildlife habitat

i) These areas can provide opportunities for bird watching, fishing, hunting, ecotourism, environmental education, passive enjoyment, and/or assistance for management of selected wildlife species.

f) Restored watersheds

g) Reservoirs for water storage

Short- and Long-term Land Use Considerations after Clay Deposition

1. As stated above, the landscape (elevations) of the final phosphatic clay surface is related to the method of clay deposition and the underlying landforms of the CSAs comprising the bottom of the clay settling pond.

a) Prediction of the final phosphatic clay surface that is well into the differential settling phase is possible if the original landform is known or can be estimated.

i) Historical aerial photography of phosphate mining areas is available for most years. Georeferencing the aerial photography in a geographic information system (GIS) could assist with estimating the original landforms existing in the CSAs before the introduction of the phosphatic clays.

ii) Surveys of the disposal areas that show the locations and elevations of the mine spoils before clay disposal may also be available.

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iii) Clay consolidation modeling can be used to determine the time and elevation at which clay consolidation will approach stasis, providing an opportunity to plan for further differential settling and reducing the extent of impounded drainage after reclamation.

b) A corollary to this statement is that the landscape of a newly designed settling pond before introduction of the clays can greatly control the final phosphatic clay landscape. Therefore, it would be beneficial to base the geographic orientation of target reclamation land uses on the initial characteristics of the CSA without clay.

c) Taken a step further, future phosphatic clay disposal areas could be constructed in a manner that takes advantage of the potential for multiple-use post-reclamation landscapes. Targeted placement of leftover overburden spoils could consolidate areas of higher and lower elevations and may allow for strategic placement of stable access roadways in the post-reclamation landscape.

i) Costs for land forming before initial phosphatic clay introduction should be compared with expected lower phosphatic clay reclamation costs, coupled with an improved phosphatic clay landform and its increased value after reclamation.

ii) Given the long operational life (often exceeding 40 years from initial mining through the completion of reclamation) of the CSAs, care should be exercised when identifying potential post-reclamation land uses.

2. The incorporation of an adjustable outfall at the CSA's discharge point, or retention of the mining-operations adjustable outfall, would allow greater flexibility in adapting to continued clay consolidation during continued maintenance of drainage channels.

3. Substantial amounts of non-clay materials, used for construction of the dam, are available for the reclamation process. These materials often form the post-reclamation surface soils on the perimeter of the clay settling areas but could also be used for other purposes such as construction of roads.

A Strategy for Fully Utilizing CSAs

1. Identify potential post-reclamation land uses that will add to the local economy and the sustainability of the community and take advantage of the clay resource for environmental and agricultural purposes.

2. Develop a **plan** based on a prediction of the phosphatic clay landscape as it is likely to be well into the differential settling phase. This foresight will reduce costly intermediate development, such as the construction of inappropriately placed macrobeds.

3. The design of the multiple-use landscape means:

a) Not all reclaimed phosphatic clay land will be in commercial production. However, non-commercial areas can be utilized for water quality benefits and water supply purposes in addition to providing wildlife habitat.

b) Where clay deposits are deepest and not mixed with other materials such as overburden or sand tailing, the result will likely be the lowest clay-surface elevation at ultimate consolidation. These locations should contain isolated or connected wetlands, some of which will likely have a free water surface for some part of the year.

i) Plantings, such as cypress and other wetland tree species in what will become the lower surfaces after differential settling, can actually facilitate the dewatering process.

c) Where clay deposits are of **intermediate depth** and adjacent to deeper deposits, **filtration zones** (i.e., forested buffers) can be established with plant selection based upon expected wetness or hydroperiod (if close to a free water source).

d) Where phosphatic clay depths are relatively shallow, cropping systems and vehicle access should be established.

i) Plantings of row crops may be on or slightly across the **contour**; and

ii) Short rows mean requirements for **smaller and/or specialized equipment**. Farming on phosphatic clay is considerably different than on adjacent sandy fields. Low weight, clay-specific equipment can reduce energy needs and simplify land and harvesting operations.

iii) **Trafficability** of phosphatic clay is problematic during the wet season, and special consideration should be given to movement of equipment.

(*a*) **Perennial peanut** (rhizome-type) has shown to be effective when planted as a sod for traffic rows in a wide range of phosphatic clay moisture conditions.

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(*b*) Use of **specially designed equipment** suitable for phosphatic clay areas has been explored, but advances in articulation and robotic arms are still to be investigated.

(*c*) Replacement of topsoil (if available), overburden, or sand tailings in areas where equipment use is needed may improve access.

e) Soil characteristics on CSAs may be enhanced through use of **municipal composts, water treatment residuals, or biosolids**.

i) Use of **municipal composts** to improve soil characteristics in the reclaimed clay disposal areas would:

(*a*) Offer a disposal area for the municipality at no or low cost;

(*b*) Recycle nutrients and organic matter in a **sustainable** way;

(*c*) Provide needed organic matter to the phosphatic clay soils, which will help with **tillage, water control,** and **nutrient recycling;**

(*d*) Repress other plant competitors (e.g., Carolina willow) in areas reclaimed to native habitats, allowing planted trees to form a canopy more quickly.

ii) Municipal **waste-stream separation techniques** have improved greatly, and hazards of trace metals have been reduced.

iii) Some phosphatic clay land could be used to compost municipal organics on a commercial scale.

(*a*) Several large vegetable and citrus corporations in southwest Florida already do **commercial composting**, which benefits plants growing in these sandy soils and assists municipalities in a sustainable manner.

f) The multiple-use landscape concept offers the promise of a water-efficient system that will allow agricultural production while posing little or no additional burden on the underlying aquifers. To assure efficient use of water available within the CSA and to maintain high water quality, a **Water Use Plan** should be devised.

i) Water for operations can be harvested from pools within the lower elevations of the CSA.

ii) Include filtration zones, such as forested buffers, between agricultural areas and wetlands to trap nutrients in native biomass.

iii) Monitor discharge points for excess nutrient levels.

(*a*) In clay areas where macrobeds have been employed for crop production, a substantial amount of rainfall can be assimilated without appreciable runoff. However, when runoff events do occur, sediment, total phosphorus (TP), and turbidity are environmental concerns. As a result, runoff waters from cropped areas on CSAs are typically not suitable for discharge to the environment.

(*b*) Small catchment basins within the CSA have proven ineffective at removing the particulate matter and TP in runoff from the cropped areas. Chemical treatment may be required before discharge of runoff waters. Small amounts of alum would remove >99% of the TP in the runoff waters. Alternatively, the runoff waters from the cropped areas can be routed through filtration zones within the CSA and ultimately to on-site wetlands where the water can be stored and potentially reused.