DETAILED GEOLOGIC MAPPING OF AQUIFER RECHARGE AREAS IN THE UPPER COASTAL PLAIN OF SOUTHWEST GEORGIA

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Abstract. Detailed geologic mapping on a scale of 1:24,000 has better defined the recharge areas of the Upper Floridan, Claiborne, Clayton and Cretaceous aquifers between the Flint River and the Chattachoochee River. Mapping over an eight year period that covered twenty-four 7.5" quadrangles was funded, in part, by the U.S. Geological Survey's STATEMAP program. In addition to classical field mapping, interpretive geologic maps of each quadrangle were derived and developed as GIS coverages.

Field observations suggest the aquifer recharge areas are more complex than previous studies of ideal geologic sections. Several periods of extensive weathering and erosion in the geologic record, particularly in the current recharge areas of the Upper Floridan, Claiborne, Clayton and Cretaceous aquifers, have resulted in removal of portions of the stratigraphic units that host these aquifers, removal of portions of the confining units, and adversely altered the porosity and permeability of the updip portions of these aquifers. Multiple episodes of paleo-groundwater movement recorded as cross-cutting alteration patterns in outcrops may further degrade optimal aquifer recharge in these areas. Previously unrecorded folding during the Tertiary may alter groundwater flow patterns, also.

INTRODUCTION

The U.S. Geological Survey provides funding to promote geologic mapping by state geological surveys in a program called STATEMAP. Each state's geological survey determines areas that need geological mapping to address important issues within their particular state. Beginning in the 1970's, different portions of the Upper Coastal Plain were mapped at a scale of 1:100,000 (Hetrick (1990, 1992, 1996; Hetrick and Friddell, 1990). At the initiation of the Georgia Geologic Survey's participation in the STATEMAP program, the Upper Coastal Plain from the Savannah River to just west of the Flint River had been mapped (Fig. 1). The goal of the Georgia Geologic Survey was continuation and eventual completion of that mapping to the Chattahoochee River. Mapping of the Upper Coastal Plain has provided significant geologic information with which to address needs such as 1) protection of aquifer recharge areas, 2) rapidly increasing population in the Augusta - Milledgeville – Macon corridor, and 3) the economically important kaolin and fuller's earth industries in central and eastern Georgia.

In the area covered by the STATEMAP program (Fig. 1), Upper Cretaceous to Miocene sediments dip to the south and southeast, and contain several aquifers important to communities and the large agricultural industry in southwest Georgia. This area is the recharge zone for the highly productive and utilized Floridan, Claiborne, Clayton and Upper Cretaceous (Providence) aquifers in south and southwest Georgia.

Sediments that are exposed in the STATEMAP area range in age from the Upper Cretaceous to the Miocene. Significant aquifers are hosted by stratigraphic units that are generally porous and permeable sandstones and limestones in the Georgia Coastal Plain. Adjacent stratigraphic units that are generally more argillaceous, i.e. clay-rich, act as aquicludes and tend to confine the aquifers. Stratigraphy and aquifers are summarized in Table 1. In general, regional dip of the Upper Cretaceous and Tertiary sediments is on the order of 10 to 30 feet per mile to the southeast. The most significant groundwater recharge will most commonly occur where these aquifers are exposed at the surface.

Important agricultural lands that extend from the vicinity of Plains to the east and south are underlain principally by argillaceous sandstone of the Miocene Altamaha Formation. In addition to providing a relatively fertile substrate, this stratigraphic unit protects the underlying, older, relatively soft sands and aquifers from economically disastrous erosion such as at Providence Canyon. Understanding the extent and thickness of the Altamaha Formation is important to aquifer and agricultural land protection.

Economically significant bauxite and kaolin deposits are being mined in the vicinity of Andersonville. Additional kaolin deposits that have been identified west of Richland as a result of the current mapping could have an important impact on an economically depressed area of the state (Cocker, 2003, 2004).

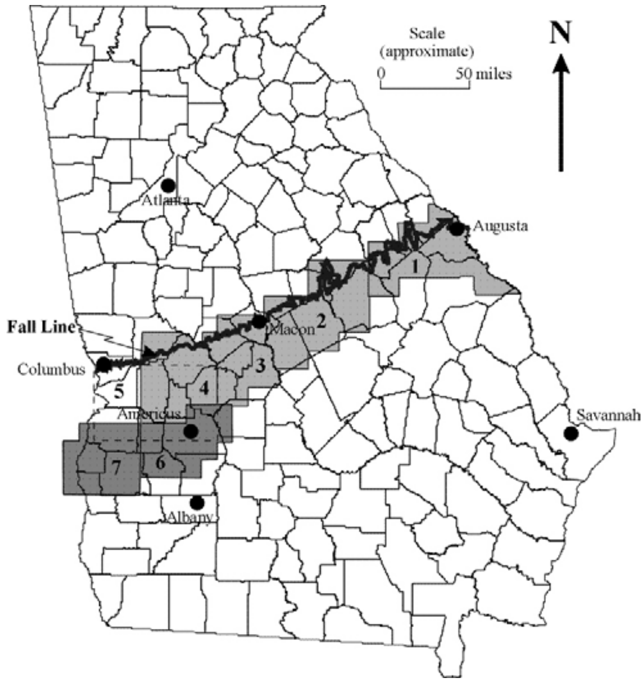

Figure 1. Location of STATEMAP geologic mapping and other recent mapping in the Upper Coastal Plain of Georgia.

Earlier maps include: 1) Hetrick (1992), 2) Hetrick and Fridell (1990), 3) Hetrick (1990), 4) Hetrick (1996), and 5) Reinhardt and others (1994). STATEMAP map areas include: 6) Cocker (2003) and 7) Cocker (in progress).

METHODS

Production of detailed geologic quadrangle maps consists of three main parts: 1) examination and mapping of outcrops, 2) digital mapping and attributing the outcrops on digital 1:24,000 quadrangle topographic base maps, and 3) compilation of digital interpretive geologic maps. Shallow core drilling is utilized to provide subsurface information on geologic contacts and identification of geologic units particularly where surface exposures are poor to non-existent. The drill rig used in this investigation is a Formost Mobile model B-59 rig. Coring was done with 4 1/4 inch ID hollow stem augers equipped with a wireline, continuous coring system. Cross-sections were prepared from drill hole data and surface geologic maps.

Outcrop and drill hole locations were plotted on digital 1:24,000 quadrangle topographic base maps in ArcEdit directly from field maps. Geologic maps were compiled onscreen in ArcEdit on digital 1:24,000 quadrangle topographic base maps and attributed in ArcView. ArcPlot programs were written to prepare hard copies of each geologic map.

RESULTS

Field observations indicate the aquifer recharge areas are more complex than studies of ideal geologic sections. Several periods of extensive weathering and erosion in the geologic record, particularly in the current recharge areas of the Upper Floridan, Claiborne, Clayton and Cretaceous aquifers, have resulted in removal of portions of stratigraphic units that host these aquifers, removal of portions of confining units, and degradation of aquifer porosity and permeability within the up dip portions of these aquifers. In addition, multiple episodes of paleo-groundwater movement resulted in further degradation of the aquifers.

Unconformities and their relation to aquifer quality and integrity

Sediments that are deposited in an essentially continuous sequence are described as conformable. When significant breaks occur in sediment deposition during which subaerial or subaqueous weathering or erosion occurs, these sediments are unconformable. Contacts between unconformable sediments are referred to as unconformities. Within the STATEMAP area, unconformities were identified at the base of the Clayton, Nanafalia and Tuscahoma Formations, the Claiborne Group, the residuum of Eocene – Oligocene sediments, and the Altamaha Formation. In addition, an intraformational unconformity is present within the Nanafalia Formation.

In the present STATEMAP area, erosion may remove part or all of an underlying unit. If the up dip portion of an aquifer were removed and subsequently covered by relatively impermeable sediments, then the recharge potential of that

Table 1. Generalized stratigraphy of Upper Coastal Plain sediments and corresponding aquifers within the STATEMAP area.

Period	Epoch	Stratigraphic Unit	Aquifer
Tertiary	Miocene	Altamaha Formation	
	Eocene to Oligocene	Residuum from Eocene and Oligocene limestones	
	Eocene	Ocala Group (limestones)	Upper Floridan
	Eocene	Clinchfield Formation (sandstone)	
	Eocene	Claiborne Group (sandstones)	Claiborne
	Paleocene to Eocene	Tuscahoma Formation (clay)	
	Paleocene	Nanafalia Formation (sandstones and clay)	
	Paleocene	Clayton Formation (limestone)	Clayton
Cretaceous	Gulfian	Providence Formation (sandstone)	Providence
		Ripley Formation (clay and siltstone)	
		Cusseta Sand	Cusseta
		Bluffton Formation (sandstone)	Eutaw-Blufftown
		Eutaw Formation (sandstone and clay)	

aquifer is severely decreased. Channels cut through impermeable sediments would allow ground water communication between the upper and lower aquifers.

Surficial and Ground water weathering and alteration

With the exception of significant differences in grain sizes, most near-surface primary sedimentary textures, colors, and fossils have been altered or obliterated by intensive, sub-tropical, surficial weathering or groundwater alteration (Cocker, 2003, 2004; Cocker and Costello, 2003). In addition, overlapping or cross-cutting relations represent several episodes of alteration and weathering. Weathering and alteration tend to degrade porosity and permeability in aquifers through downward movement and concentration of clay minerals and precipitation of new minerals in pore spaces.

Most sediments in the Upper Coastal Plain are sandstones or limestones. Sandstones consist primarily of quartz, with lesser amounts of feldspar, mica and clays derived from erosion of crystalline, generally granitic rocks, in the Georgia Piedmont. Limestones consist primarily of calcite, with lesser amounts of clays and quartz. Intensive weathering of the feldspar and clay eventually produced kaolinite clay and bauxite principally by the addition of water and the removal of dissolved silica. Limestone weathers to residual clay and chert where silica-bearing ground water is present. Primary iron-bearing minerals (perhaps amphiboles, biotite or glauconite) were altered to iron oxides.

Iron oxides and clays mobilized by ground water or surficial weathering generally affected most of the presently exposed sandstones. Primary sedimentary structures, such as cross-bedding, are commonly obliterated by pervasive red, yellow, and brown staining, irregular staining referred to as mottling. Depth of more recent, surficial, groundwater alteration is on the order of 10 to 30 feet.

In the Andersonville district, upper portions of the Tuscahoma Formation are commonly rusty orange to rusty tan, whereas lower portions are mainly dark gray. This represents an oxidation-reduction front in the groundwater regime. The contact between the rusty and dark gray parts may be irregular or conformable to the upper contact. Variations in the extent of this oxidation are not related to the present surface and represent paleo-oxidization by circulating ground water in the lower part of the Claiborne sediments or surface weathering prior to Claiborne sedimentation.

Periods of dissolution and chertification of the Paleocene Clayton Formation, Middle to Upper Eocene and Oligocene carbonates were exposed to surficial or near-surface weathering prior to deposition of the overlying sediments. Chert clasts in the Tuscahoma and Nanafalia Formations indicate that at least some dissolution and chertification of Clayton carbonates occurred prior to Nanafalia deposition. Locally abundant chert and clay clasts, especially in the basal conglomerate of the Altamaha Formation, indicate intensive dissolution and chertification of Middle to Upper Eocene carbonates, and Oligocene carbonates occurred prior to deposition of the Altamaha Formation. Dissolution of these carbonates left a residuum of sticky clay and chert that is impermeable to groundwater movement. On older, state-scale maps, most of the areas depicted as recharge zones for the carbonate-hosted aquifers are actually covered by this impermeable residuum with little or no apparent recharge potential.

Clays in the updip portion of the Nanafalia Formation were exposed to a period of very intensive surficial weathering and near surface groundwater alteration. Primary sedimentary textures and structures in the original clays were obliterated by secondary kaolinization and bauxitization. Although bauxitization increased the porosity of these sediments, subsequent kaolinization decreased their porosity. Subsequently, erosion and deposition of an upper sandy facies cut channels into the lower kaolin and bauxite.

Iron oxides are generally found as a reddish stain characteristic of most exposed rocks in the southeastern United States. Locally, conditions resulted in precipitation of iron oxide plus or minus silica in the form of irregular crusts. Some of these are impermeable, and many appear discontinuous in extent. Such relations may result in perched water tables or other impediments to groundwater recharge.

Cross-cutting patterns and types of iron oxide precipitation indicate multiple episodes of iron-bearing groundwater movement. An exposure of the Altamaha Formation sandstone displays an early, pervasive, light red stain overprinted by intersecting linear patterns of darker red staining that appear to imitate jointing. Similar linear patterns of iron-oxides cut and overprint an earlier pervasive kaolinization developed in the more argillaceous portions of the Altamaha Formation. Other, larger joints that are also found in the Altamaha Formation illustrate multiple episodes of iron-oxide staining, kaolinization, and bleaching adjacent to the joint surfaces.

Mottling consists of numerous white or light, yellow- to red-stained whitish, generally ovoid cores with darker red to yellowish brown outer envelopes. This appears to represent local migration and precipitation of kaolinite and iron-oxides. Mottling is most commonly developed in the Altamaha Formation and to a limited extent in the Nanafalia Formation. Although most mottling in the Altamaha Formation appears to be related to the current surface, one exposure depicts tilting of two episodes of mottling that occurred prior to development of the present surface.

Structural modifications

Numerous low amplitude folds and reversals of dips indicating folding will, at least locally affect the flow patterns of ground water. In addition, poorly exposed major faulting, such as the Andersonville fault, with approximately 100 feet of displacement and a lateral extent of 45 miles may interrupt or severely alter the flow patterns of ground water on a regional scale.

CONCLUSIONS

Detailed mapping of the aquifer recharge areas in the Upper Coastal Plain of Georgia indicates that assumptions about recharge, as well as groundwater movement in these areas may be incorrect. Structural modifications of the the Upper Coastal Plain stratigraphy may affect the flow patterns of ground water on both local and regional scales. In addition to further mapping in this portion of the Upper Coastal Plain, previously mapped areas in the Upper Coastal Plain should be reexamined with considerations to the effects of unconformities and surficial and groundwater alteration of the aquifer-hosting sediments.

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