STATEMAP PROPOSAL - VIRGINIA

Submitted in response to USGS Program announcement
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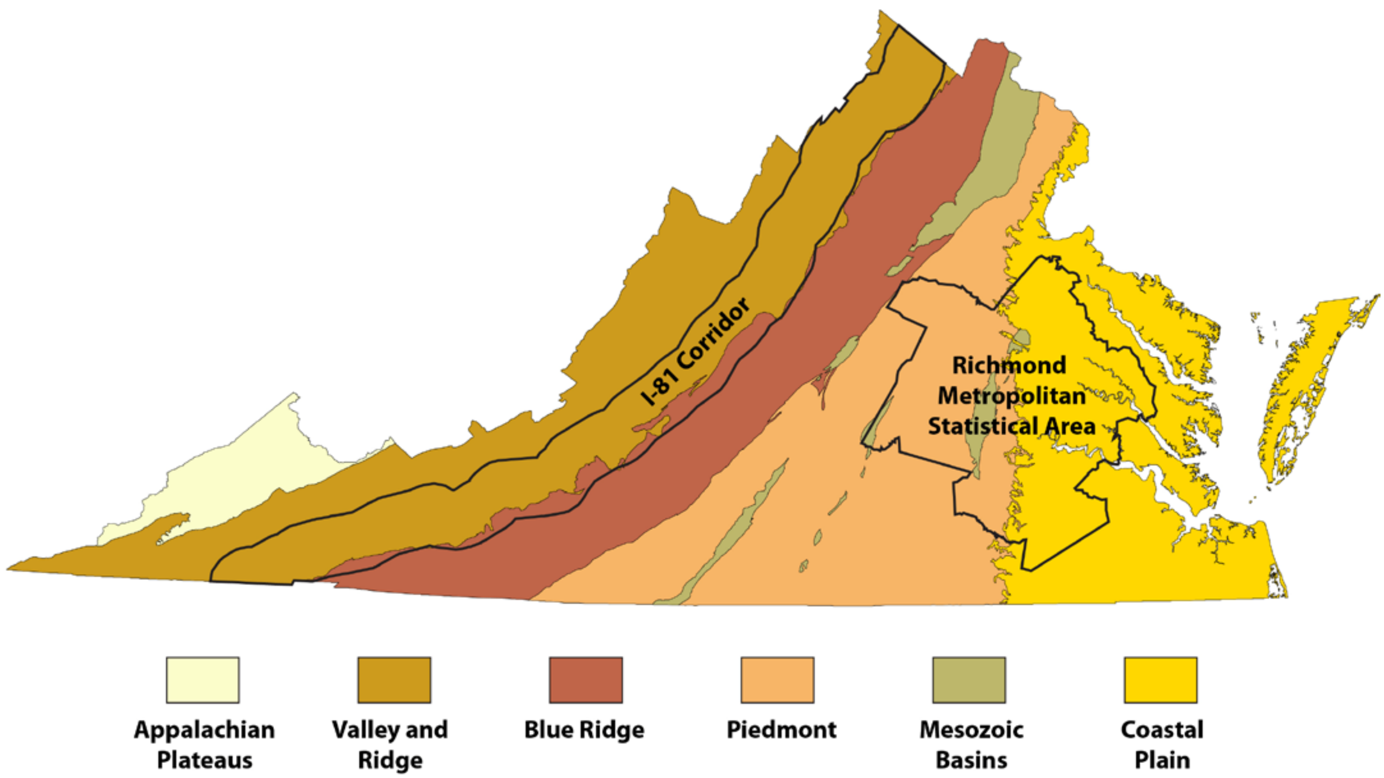

Virginia Department of Mines Minerals and Energy

November 6, 2013

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INTRODUCTION

The Virginia Department of Mines, Minerals and Energy, Division of Geology and Mineral Resources (DGMR) seeks continued funding for geologic mapping along the Interstate 81 corridor and in the Richmond Metropolitan Statistical Area. These long-term projects focus our efforts on two regions of Virginia that are experiencing rapid growth and are in great need of new and accessible geologic information. The maps we produce will continue to enhance Virginia's ability to develop and conserve natural resources in a safe and environmentally sound manner to support a more productive economy.

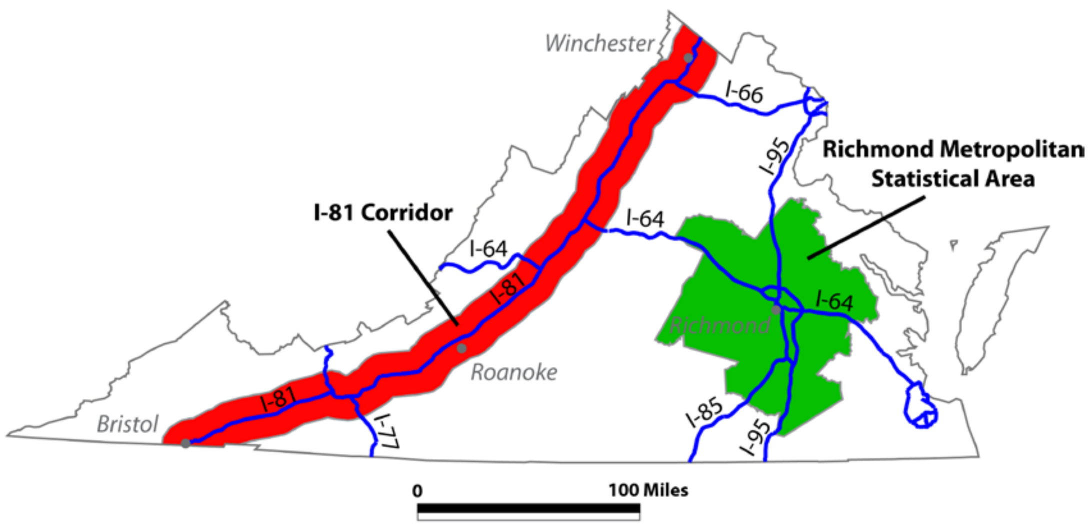

Figure 1. Locations of project areas.

Long Range Plan

In 2003, DGMR's Geologic Mapping Advisory Committee (GMAC) agreed that geologic mapping was needed in Virginia to locate water resources, develop economic products such as aggregate and sand, identify and mitigate the risks from geologic hazards, protect natural resources, site waste disposal facilities, and develop roads and other infrastructure. The GMAC and DGMR staff evaluated areas in Virginia with respect to these needs and Virginia's diverse geology and natural resources (Figure 2). The GMAC determined that mapping in three areas would provide the greatest benefit: western Virginia, particularly along the I-81 corridor; the Richmond metropolitan area; and along the I-64 corridor between Richmond and Virginia Beach. A long-term mapping strategy was developed for three areas: The I-81 Corridor, The Richmond Metropolitan Statistical Area, and the Williamsburg 30- x 60-minute quadrangle. These strategies considered regional needs, development patterns, mineral resources, the location of existing mapping, and staff resources. Mapping and compilation in one of these areas, the Williamsburg 30- x 60-minute quadrangle, was completed in 2013. This proposal seeks funding for continued new mapping and compilation of existing maps along the I-81 Corridor and in the Richmond metropolitan area.

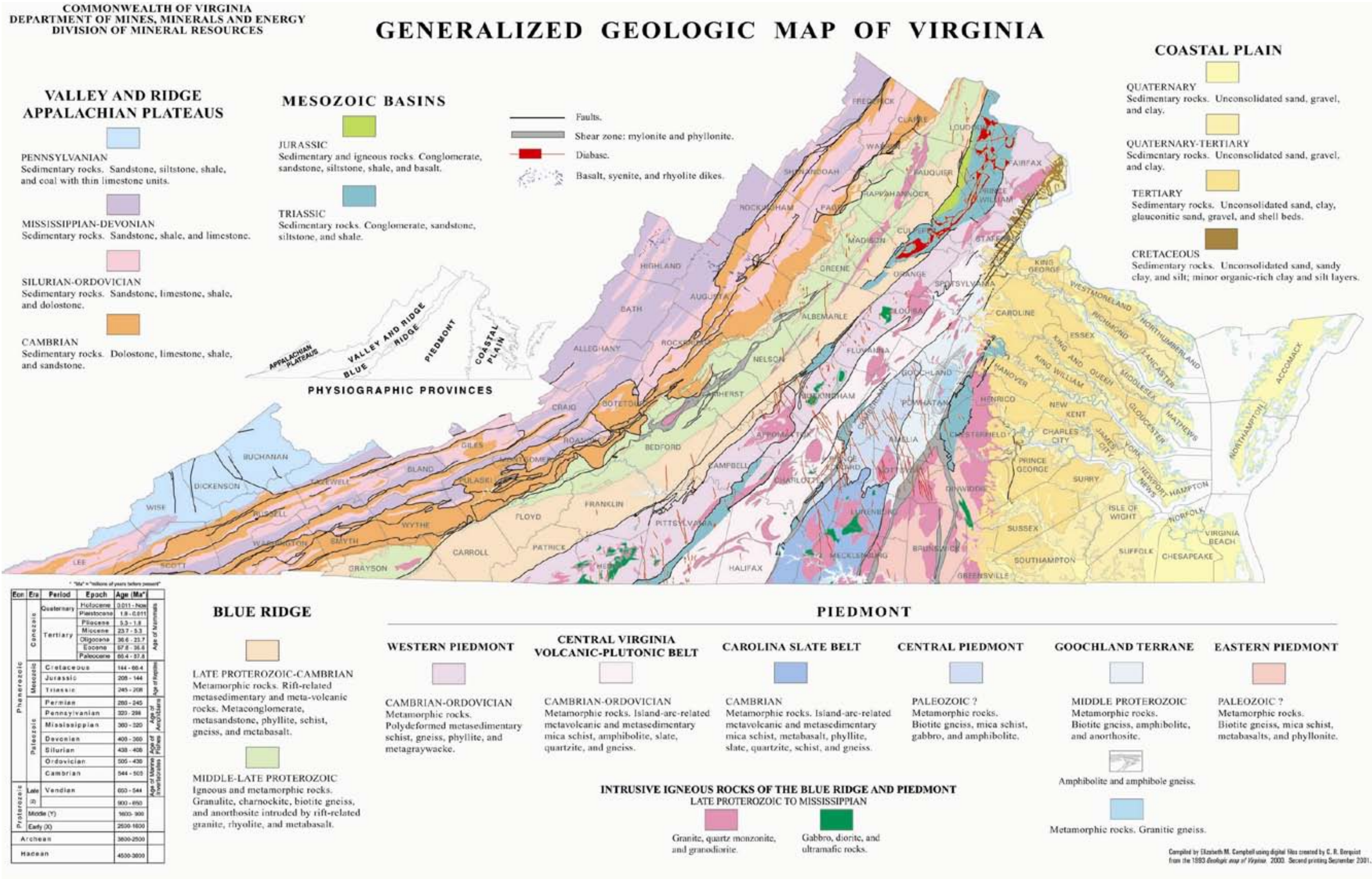

Figure 2. Generalized geologic map of Virginia.

Virginia Growth

Virginia is home to over eight million people (Weldon Cooper Center, 2012). The population of our state is expected to reach almost ten million people by 2030 (U.S. Census Data, 2005). Two thirds of this growth is expected in the Washington D.C., Richmond, and Virginia Beach–Norfolk–Newport News areas, which have largely been mapped. Much of the remaining growth will occur near major highways such as Interstate 81.

Nearly one million people currently live within the twelve counties and ten cities that straddle I-81 (Weldon Cooper Center, 2012). The population in this region is expected to grow more than 15 percent by 2030 (Virginia Employment Commission, 2003). Approximately 90 percent of this growth is expected to occur in rural areas that are currently unincorporated.

Approximately 1.2 million people live in sixteen counties designated as the Richmond Metropolitan Statistical Area (Weldon Cooper Center, 2012). Municipal centers include the cities of Richmond, Petersburg, Hopewell, and Colonial Heights. The population of this area is expected to grow approximately 35 percent by 2030 (Virginia Employment Commission, 2003). Almost all of this growth is expected to occur outside of existing city boundaries.

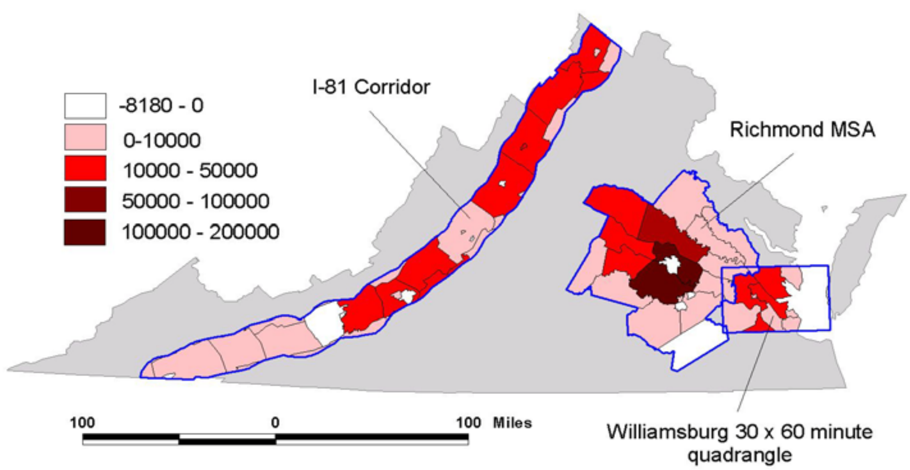

Figure 3. Projected population change, by county and municipality, in proposed project areas from 2000 to 2030 (Virginia Employment Commission, 2003).

Geologic Mapping and Water-related Studies

Long-term geologic mapping projects in Virginia are focused on areas of rapid growth, but large portions of both project areas remain rural. In rural Virginia, most households rely on private wells, and public water supplies are often sourced from ground water. Mapping in both project areas currently supports water-related studies in several ways. The USGS Karst project relies on detailed geologic maps produced cooperatively with Virginia's Division of Geology and Mineral Resources in the I-81 Corridor to provide control for ground-water models. Geologic mapping in the Shenandoah Valley supports water quality restoration efforts in the Smith Creek basin, one of three designated "Chesapeake Bay showcase watersheds." DGMR's geologic mapping in the Richmond MSA has identified previously-unknown faults that offset Coastal Plain sediments. These faults may serve as hydraulic boundaries for regionally significant groundwater sources such as the Potomac Aquifer, the subject of a recent USGS study (see Statement of outcome for more information).

The locations of the I-81 Corridor and Richmond MSA mapping areas are well suited for additional water-related studies. The I-81 Corridor project area contains headwaters of the James, New, Roanoke, Shenandoah, and Tennessee River basins. Much of the project area is underlain by carbonate bedrock with well-developed but poorly understood karst aquifers. Faults in the area have a strong influence on the hydrogeology, and control the locations of thousands of deep-source springs. DGMR's geologic maps are the primary source of location data for faults and karstic bedrock units. The Richmond area MSA project is centered on the lower portion of the James River, which in 2013 was named to a list of "America's Most Endangered Historic Places," due to pollution and development pressure. The James, which feeds into Chesapeake Bay, is also known as "America's First River." Beginning in 1607, its banks were the site of Jamestown, the first successful English settlement in the New World, where settlers relied on fresh groundwater as an alternative to brackish river water. Virginia recently designated most of its Coastal Plain province as a capacity use area for groundwater supply, and a 3-D geologic model would be a tremendous resource for this developing region.

Both the I-81 Corridor and Richmond MSA projects could easily be expanded to include the collection of subsurface data through drilling and geophysics to support assessment of regional aquifers. DGMR already has a substantial body of vertical borehole data, developed as part our STATEMAP work, for the Coastal Plain portion of the Richmond MSA. New projects could also be developed to characterize the subsurface geology of areas with greater potential for natural gas production, including the Taylorsville Basin, areas in western Virginia underlain by the Marcellus shale, and active natural gas production areas in southwestern Virginia. Our GMAC has always appreciated the importance of geology in addressing water issues, and is supportive of program expansion if funding becomes available.

INTERSTATE 81 CORRIDOR PROJECT

Introduction

DGMR proposes to continue a concentrated multi-year effort to: A) complete new 1:24,000-scale geologic mapping; and B) digitally compile existing geologic maps along the entire I-81 corridor in Virginia. This portion of the Appalachian Valley is where most of the population lives, works, and travels on a daily basis. It is home to a variety of farms, industries, and commercial enterprises. I-81 is also a nationally significant transportation corridor that connects manufacturers and markets from the southern and northeastern United States.

For the purpose of this study, the I-81 corridor is defined to extend for 10 miles (16.1 km) on either side of the highway (Figure 1). DGMR plans to complete 1:24,000-scale geologic mapping of all quadrangles that are wholly or substantially within this corridor. DGMR also plans to selectively map quadrangles that are adjacent to the I-81 corridor in areas of current or projected future growth.

Intermediate products for this study will be 1:24,000-scale geologic maps of quadrangles, to be published in digital form, and a series of open-file digital reports that contain GIS files for the current extent of the geologic compilation. The final product will be a 1:24,000-scale digital compilation of the entire corridor.

Location and Geologic Setting

I-81 extends for 325 miles in western Virginia, along the Appalachian Valley. It is the longest interstate in Virginia and has 90 interchanges, including intersections with Interstates I-66, I-64, and I-77. Two proposed Interstates, I-73 and I-74, will also intersect with I-81. Since its completion in the 1960s, I-81 has become the “main street” of western Virginia, serving as a corridor for travel, commerce, and development.

Industries and commercial businesses have located in the I-81 corridor to take advantage of the transportation system. Abundant high-quality ground-water supplies in some areas have also attracted industries. The Radford and Holston Army Ammunition plants are major facilities in the corridor. Away from municipal centers, agriculture is dominant. The twelve counties that I-81 passes through contain approximately 11,750 farms on approximately 1.66 million acres (U.S. Department of Agriculture, 2007). This includes nearly 10,000 livestock operations.

The Appalachian Valley contains headwater portions of five major watersheds. Three of these watersheds are located on the eastern side of the eastern continental divide. The Shenandoah-Potomac and James rivers begin in the north and north-central parts of the Valley. Water from these rivers eventually flows into the Chesapeake Bay. The Roanoke River begins in the central Valley and flows into North Carolina where it enters Albemarle Sound and ultimately the Atlantic Ocean. The New and Tennessee rivers, in the southern part of the valley, flow northwest and southwest, respectively, and ultimately enter the Mississippi River watershed.

The I-81 corridor is predominately underlain by clastic and carbonate sedimentary rocks of the Valley and Ridge geologic province. Metamorphic and igneous rocks of the Blue Ridge geologic province underlie a portion of the eastern edge of the corridor. Early to late Paleozoic-age limestone, dolostone, sandstone, and shale comprise much of the Valley and Ridge province. These rocks formed from sediments that were deposited in a variety of terrestrial and marine settings. Folding and faulting of these rocks, predominantly during the Alleghanian Orogeny, has produced complex geologic structures. Subsequent erosion has resulted in a distinctive topography that is dominated by alternating linear ridges and valleys. The stratigraphic sequence in the Valley and Ridge geologic province was mapped at a scale of 1:250,000 by Butts (1933; 1940). Subsequent 7.5-minute quadrangle, county, and 30- x 60-minute quadrangle mapping in portions of the project area has identified additional evidence for faulting and folding and refined the stratigraphy. STATEMAP mapping and compilation projects continue to identify map-scale structures, harmonize the portrayal of regional tectonic features, and establish consistent stratigraphic nomenclature in this portion of western Virginia.

Rocks of the Blue Ridge geologic province are Middle to Late Proterozoic and early Paleozoic in age. The older rocks exist as basement and are nonconformably overlain by the younger rocks. Both groups of rocks may overlie a major decollement and sit atop rocks that are thought to be correlative to those exposed in the Appalachian Valley. Contacts between Blue Ridge rocks are commonly sheared, making original relationships difficult to determine.

Purpose and Justification

Water resource location, economic product development, geologic hazard identification, natural resource protection, and infrastructure development are critical issues along the I-81 corridor. Locating aggregate sources and identifying geologic hazards is very important as Virginia considered capacity improvements for I-81. The need to locate additional water resources continues as development expands. The need to protect natural resources including river systems, forests, ground-water supplies, mineral resources, cave systems, and open space is also increasing in response to development pressures. This project will provide useful information at an appropriate scale to address the issues identified by the GMAC in the following ways:

Water Resource Location

Cities and towns in western Virginia obtain their water supplies from ground-water aquifers, surface reservoirs, or a combination of the two. Away from municipal centers, drilled wells are the primary water sources for residents, businesses, and industry. Well yields vary depending upon rock type, location, and depth. In karst and fractured rock aquifers, well yields are unpredictable. Supplies are typically adequate for residential use, but higher yield supplies for industries and municipalities are more difficult to locate. Some surficial deposits in the Appalachian Valley are significant reservoirs for ground water. Ground water residing in alluvial fan deposits supplies many businesses in the Valley, including those that require a high quality water source such as MillerCoors Shenandoah Brewery, Merck Chemical, Hershey's Chocolate, Invista, and McKee Foods. Detailed geologic mapping will provide useful information to municipalities, businesses, and industries when situating future wells.

Economic Product Development

There are 79 active mine and quarry operations in the twelve counties along I-81. These businesses produce significant quantities of crushed stone, clay, sand, gravel, dimension stone, and industrial minerals. Aggregate resources provide local sources for high-demand construction materials. Industrial minerals including iron oxides, high-calcium limestone, salt, and silica are exported, providing business income and local jobs. The potential for additional aggregate and high-calcium resources exists along the I-81 corridor. The identification of these resources for quarrying will support continued economic development in the region.

Geologic Hazard Identification

Sinkholes are significant hazards along large parts of the I-81 corridor. Many sinkhole collapses result from changes in water use, drainage, or recharge due to changes in land use and construction-related disruption of natural drainages. Landslides, debris flows, and unstable slopes are also hazards. These types of problems are common in the northern half of the corridor where the Blue Ridge Mountains meet the Appalachian Valley and in the southern half of the corridor where the hill slopes are steep. Landslides, debris flows, and extensive reworking of alluvial boulder deposits can occur during periods of heavy rainfall, such as those experienced during Hurricane Isabel in 2003 and Hurricane Ivan in 2004 (Wieczorek and others, 2009). Even on moderate slopes, some rock types and geologic structures create stability problems for structures and roads.

Natural Resource Protection

Development pressures within the I-81 corridor are resulting in changes in land use. Open space is being converted to industrial, commercial, and residential use. These changes have both positive and negative effects on the region's natural resources. In many cases, the geology can play an important role in the nature, type, and extent of these impacts. Detailed geologic maps will provide useful information to land use planners, natural resource caretakers, and environmental consultants who work in the corridor.

Water quality is a significant problem in the region and ultimately impacts water quality in the Chesapeake Bay. Although significant pollutant reduction strategies are currently underway, point and non-point pollution sources, including agricultural runoff, outdated water treatment facilities, failing septic systems, and excessive sedimentation continue to degrade ground- and surface-water quality. One third of monitored streams and rivers in the Shenandoah-Potomac basin are not supporting designated uses that include providing aquatic or wildlife habitat, fish for consumption, public water supply, or outdoor recreation (Virginia Department of Environmental Quality, 2008).

Roads and other Infrastructure Development

A statewide expansion of I-81 continues to be considered; major widening and the building of truck-climbing lanes is nearing completion in the Lexington and Christiansburg areas. This expansion project would likely include the widening of the interstate, and possibly the installation of rail along the corridor and other improvements. Additional projects include the construction of I-73 in the vicinity of Roanoke. Commercial, industrial, and residential development and associated utilities will likely follow road construction and expansion projects. Detailed geologic maps will provide useful information to the Virginia Department of Transportation, municipal and private utilities, and private and public land developers during this process.

Science Issues

The geology of the Valley and Ridge Province in Virginia has been studied for nearly 200 years. It is a classic area of research in carbonate stratigraphy, invertebrate paleontology, and thin-skinned tectonics. Major research activities include relating lateral and temporal changes in depositional environments to orogenic activity and climate change, and unraveling the nature and timing of deformation during Paleozoic orogenies. More recent research has focused on the modeling of ground water flow in faulted and folded clastic-carbonate bedrock terrain, documenting the extent of karst systems and their role in ground water transport, and understanding the geomorphic evolution of the Shenandoah River Valley. Our mapping program directly supports all of these areas of research by providing basic geologic information and regularly consulting with researchers. In addition, our employees and contractors are regular contributors at Geological Society of America and other professional meetings.

Strategy for Performing Geologic Mapping

Most 7.5-minute quadrangles in the I-81 corridor have geologic map coverage that falls into one of the following categories: published mapping at 1:24,000 scale; unpublished or published mapping at a scale between 1:50,000 and 1:100,000; unpublished or published mapping at a scale of 1:125,000 or 1:250,000; and mapping at a scale smaller than 1:250,000 (Figure 4). Our strategy is to: A) complete new geologic mapping to bring the level of mapping in other quadrangles up to 1:24,000-scale resolution and B) compile existing blocks of published 1:24,000-scale maps. The digital geologic compilation will be expanded as new quadrangles are mapped and compiled in GIS.

Mapping will be carried out by experienced field geologists as listed in the personnel section. Field observations will be collected using Trimble Nomad GPS data loggers. Lithologic descriptions, bedding orientation, and other geologic observations will be recorded and stored with GPS coordinates in ESRI shapefile format. The shapefiles will then be uploaded to ArcMap 10.1 in the office, where the point data will be overlain on digital topographic maps and digital terrain models. The geologist will then draw the geologic map directly in ArcMap. All map features will be stored with feature-level metadata in NCGMP09 geodatabase format.

Quadrangles will be prioritized to include areas:

- where new geologic mapping is needed to address an important environmental, developmental, or natural resource issue;
- adjacent to previously compiled geologic maps;
- where existing geologic mapping is nearly 1:24,000 resolution;
- where existing geologic mapping has been completed at 1:100,000-scale.

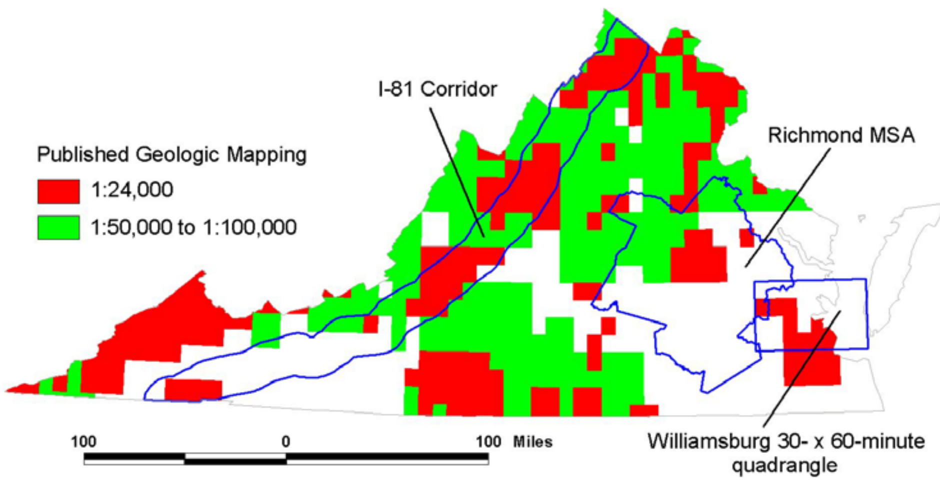

Figure 4. Published geologic map coverage in Virginia prior to the initiation of long-term mapping projects in 2003. Best geologic coverage for unshaded areas are 1:125,000- and 1:250,000-scale maps of the Coastal Plain and Appalachian Valley or the 1:500,000-scale state geologic map.

This project requires mapping approximately 70 7.5-minute quadrangles. Half of these quadrangles have not previously been mapped at a scale greater than 1:250,000. The final product will be a digital compilation of these maps and approximately 60 additional quadrangles. It is anticipated that the I-81 corridor geologic mapping project can be completed in approximately 8 years with full funding and continued collaboration with the USGS and state universities through the FEDMAP and EDMAP programs. For 2014-2015, we propose the following activities:

1. New Geologic Mapping (2.5 quadrangles)

This project will build upon our 2004 - 2013 STATEMAP geologic mapping effort, consisting of 27 quadrangles. This year, we propose to map the Hiwassee, McDonalds Mill (½), and Salisbury quadrangles (Figure 5; Table 1). All three of these quadrangles are entirely or substantially within the I-81 Corridor. The Hiwassee quadrangle was identified by Virginia Department of Transportation geologists in southwestern Virginia as their highest priority area for geologic information.

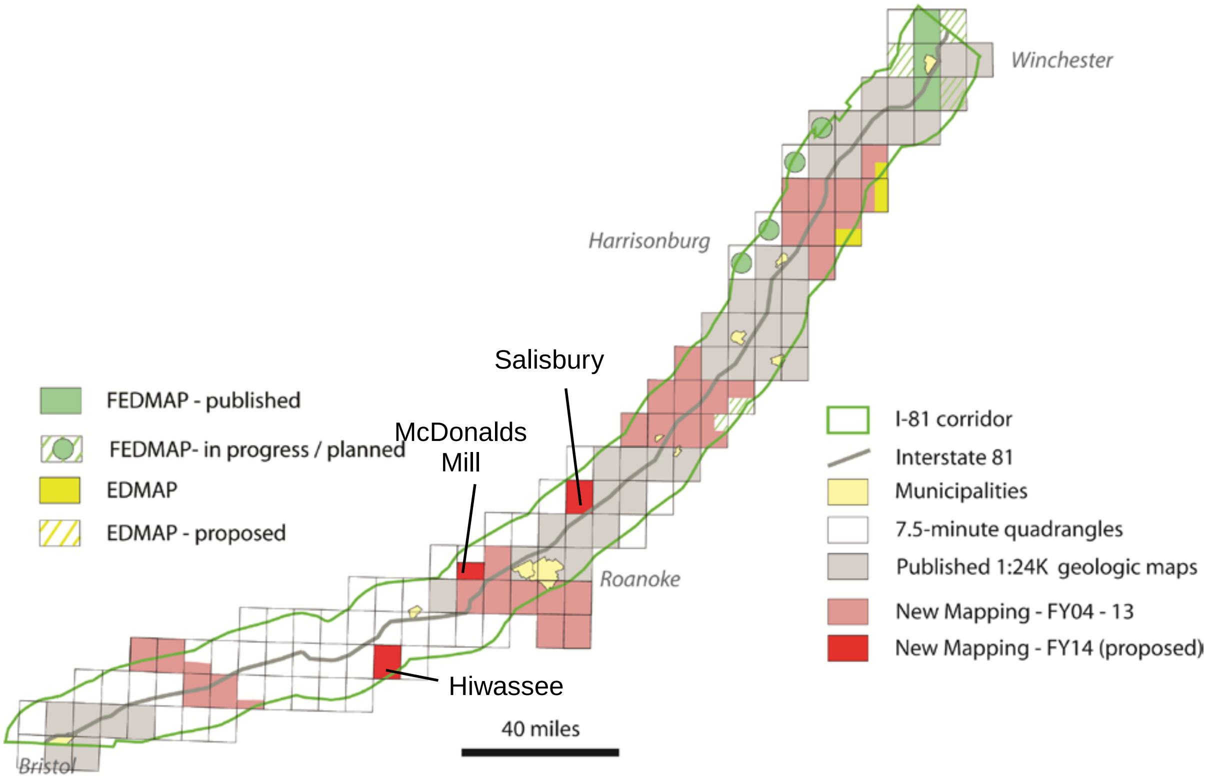

Figure 5. 7.5-minute quadrangles proposed for new geologic mapping within the I-81 corridor project. FY = Federal fiscal year.

As part of the mapping program, samples that are representative of significant map units will be collected. One portion of these samples will be submitted for whole rock chemical analysis. A second portion will be used to make thin sections. A third portion will be placed into our rock repository. Whole rock analyses will include major, minor, trace and rare earth elements. The analytical results will be used to correlate rock types and identify potential mineral resources, including high-calcium limestone. The results will be compiled into a database that is available to the public. One anticipated use is to identify the natural background concentrations of metals such as arsenic, barium, cadmium, chromium, lead, and mercury that are routinely detected in soil and ground water during environmental investigations.

In 2012, DMME began collecting samples at selected locations for exposure or burial age dating based on cosmogenic radionuclide concentrations. Deposits targeted to date include fluvial terrace and debris-flow deposits of unknown age. Having absolute age ranges for these deposits will improve our ability to make accurate surficial maps and improve our understanding of the frequency of alluvial and colluvial processes. It is also anticipated that the dating of debris-flow deposits will help establish recurrence intervals for debris-flow events in Virginia. Three sampling locations are proposed in the I-81 Corridor project area, with the locations to be determined after mapping is underway. Age dating of surficial deposits will be done in conjunction with Dr. Greg Hancock at the College of William and Mary, a nationally-recognized expert in surficial processes.

2. Geologic Compilation of Existing Maps (3 quadrangles)

This project will build upon our 2003 through 2013 STATEMAP geologic compilation, consisting of 44 7.5-minute quadrangles. This year we propose to add the Check, Hamburg, and Stanley quadrangles (Figure 6; Table 1). These quadrangles are wholly or substantially within the I-81 Corridor. Check quadrangle is currently in hand-drafted mylar format; Hamburg and Stanley were drafted in Adobe Illustrator format. All three need to be brought into the ArcGIS NCGMP09 data model. The Hamburg quadrangle requires significant field work to resolve map boundary issues with more

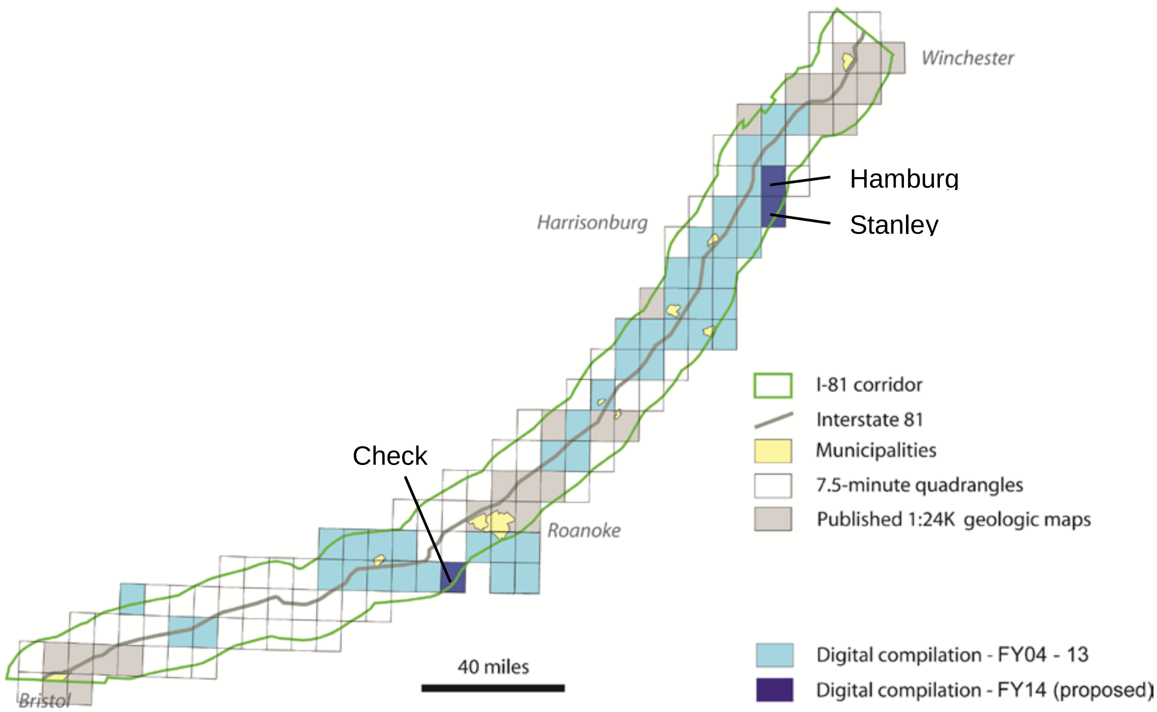

Figure 6. 7.5-minute quadrangle proposed for new digital compilation within the I-81 corridor. FY = Fiscal year.

recent mapping in adjacent areas. All quadrangles need significant field work to bring mapping of surficial deposits up to our current standard.

The digital compilation of these quadrangles will utilize the standard format for geologic map publications developed by the National Cooperative Geologic Mapping Program of the USGS (NCGMP09 standard database schema). This compilation will be an ESRI geodatabase that will include the principal map view at 1:24,000 scale, cross-sections, FGDC Digital Cartographic Standard symbology, feature-level metadata, standard lithology descriptions, geochemistry data, reference glossary, and data sources. We also intend to use these updated files to make publishable maps of all three quadrangles.

Table 1. Summary information for proposed Interstate 81 Corridor projects.

Project	Existing information		Geologic issues			Area factors		Estimated field days	Average Cost per quad
	Contacts	Data Density	Stratigraphic	Structural	Boundary	Complexity	Access		
New Mapping									
Salisbury	1:100:000 draft	Poor	Yes	Yes	No	Moderate	Fair	75	
McDonald's Mill (1/2)	1:100:000 draft	Poor	Yes	Yes	No	High	Poor	40	$81,271
Hiwassee	1:250,000 published	Poor	Yes	Yes	No	Moderate	Poor	75	
GIS Compilation									
Check	1:24,000 draft	Fair	Yes	Yes	Yes	High	Fair	20	
Hamburg	1:24,000 draft	Fair	Yes	Yes	Yes	Moderate	Fair	25	$32,429
Stanley	1:24,000 draft	Fair	Yes	Yes	Yes	High	Fair	20	

Preliminary Results and Previous Work

Preliminary Results

Between 2004 and 2013, new geologic mapping of approximately 34 7.5-minute quadrangles was completed within the I-81 Corridor, including 6 quadrangles mapped through FEDMAP and 1.25 quadrangles mapped through EDMAP. Our current STATEMAP project involves mapping the Glenvar (½), Rileyville (½), and Timberville (¼) quadrangles.

Our 2003-2013 digital compilation projects include a total of 44 1:24,000 geologic maps along the Interstate 81 corridor (Figure 6). Newly acquired and original field data have also been incorporated into the compilation. Approximately 50 months of fieldwork have been completed to resolve map boundary discrepancies, changes in stratigraphic nomenclature, structural complexities, and to provide new data upon which to base cross-sections. Our current STATEMAP digital compilation for the I-81 Corridor project includes the revision and compilation of the Pilot and Woodstock quadrangles.

New mapping and targeted remapping for this project is helping to refine the stratigraphy and structure of the Valley and Ridge and adjacent Blue Ridge provinces:

- Remapping along the Blue Ridge front in the Crimora, Waynesboro East, and Waynesboro West quadrangles in 2004-2005, supported by seismic profiles acquired after historic maps had been published, provided evidence for the existence of the Blue Ridge Fault separating Chilhowie Group rocks from those of the Rome Formation (Williams and others, 2006).

- Mapping in the Boones Mill, Garden City, and Hardy quadrangles in 2004-2005, supported by geochemical analyses, established genetic relationships among deformed plutonic and volcanic rocks of the Blue Ridge and inner Piedmont (Henika, 2006; Henika 2007).

- Field work in the Marion and Atkins Quadrangles in 2005-2007 redefined the Hungry Mother Creek and Greenwood faults as erosional remnants of a thrust that overlies the Saltville sheet. Mapping in the Augusta Springs quadrangle in 2006-2007 confirmed the existence of a significant structure, the Little North Mountain Fault, separating the Shenandoah Valley from the Allegheny Ridge and Valley (Coiner and Wilkes, 2010).

- Mapping in the Elkton West and Stanley quadrangles confirmed the presence of east-directed backthrusts within and to the east of the Massanutten Synclinorium and has redefined the nature of the Stanley Fault (Heller and others, 2007; Kirby and others, 2008; Whitmeyer and others, 2009).

- Geochemical analyses completed to support the project provide data on naturally-occurring concentrations of potentially hazardous metals in bedrock and information about the acid-forming potential of shales in the Shenandoah Valley (Coiner and others, 2007).

- Mapping of surficial deposits in the Elkton West and Tenth Legion quadrangles has led to an improved understanding of debris-flow occurrence along the Massanutten Range (Heller and Eaton, 2010).

- Field work in the Broadway and New Market quadrangles has increased the known length of the Saumsville Fault by 25 km; it now appears that this structure may link the North Mountain and Pulaski fault systems.

- Mapping in the Ironto and Blacksburg quadrangles in 2011-2012 has led to an improved understanding of the Salem thrust sheet and the relationship between faulting and karst development (Henika, 2012a, 2012b).

- Field work in the Big Levels quadrangle in 2012 has revealed multiple generations of alluvial fan deposits.

- Recent mapping in the Glenvar quadrangle shows that portions of Fort Lewis Mountain that have previously been interpreted as bedrock outcrops of Mississippian Price Formation may actually be large, intact landslide slump blocks from the interior of the Catawba Syncline.

- Recent mapping in the Glenvar quadrangle identified several north-west, south-east striking cross faults that appear to be related to the nearby Mowles Spring Fault Zone which has recently hosted a series of small earthquakes (Henika, and Chapman, 2010).

- Cosmogenic dating of a terrace 12 meters above the North Fork of the Shenandoah River in the Toms Brook quadrangle produced a model age of 340Ka, suggesting a local incision rate of 35m/My and a lateral migration rate of 1.3m/Ky. Future age dating of terraces will allow us to better understand the landscape evolution of the Shenandoah-Potomac River basin.

Previous work

Portions of the Check quadrangle have been mapped in several Virginia Tech master's theses at scales ranging from 1:24000 to 1:62,500. This student thesis-derived field data was supplemented by other graduate students and compiled on mylar by M.J. Bartholomew in the early 1980's, but never published. More recent mapping in the Roanoke area and on adjacent quadrangles (Bent Mountain, Elliston, Ironto, Pilot and Callaway) has identified several additional structural and stratigraphic issues that must be resolved during the existing digital compilation of the Check quadrangle.

The Hamburg quadrangle was mapped by Biggs (2004) but never published. A portion of the Hiwassee quadrangle was mapped for a Ph.D. Thesis (McDowell, 1968). The McDonalds Mill quadrangle was mapped at 1:100,000-scale for an unpublished compilation of the Radford 30- x 60-minute quadrangle. The Salisbury quadrangle was mapped at 1:100,000-scale for an unpublished compilation of the Buena Vista 30- x 60-minute quadrangle. The Stanley quadrangle was mapped through EDMAP by Dr. Steve Whitmeyer and students at James Madison University.

Deliverable Geologic Maps

The deliverables for this project will be:

1. Geologic map and cross-section of the Hiwassee quadrangle.
2. Geologic map and cross-section of south half of the McDonalds Mill quadrangle;
3. Geologic map and cross-section of the Salisbury quadrangle;
4. Digitally compiled geology and cross-sections as GIS files for the Check, Hamburg, and Stanley quadrangles (paper copies of each quadrangle that is part of the compilation will also be provided).

RICHMOND METROPOLITAN STATISTICAL AREA PROJECT

Introduction

DGMR proposes to continue a multi-year effort to complete 1:24,000-scale geologic mapping and digital compilation of existing geologic maps in a portion of a 16-county area that has been designated by the U.S. Office of Management and Budget as the Richmond Metropolitan Statistical Area (MSA). According to the U.S. Census Bureau website, “the general concept of a metropolitan or micropolitan statistical area is that of a core area containing a substantial population nucleus, together with adjacent communities having a high degree of social and economic integration with that core.” DGMR and the GMAC have targeted the Richmond MSA for investigation because it is a recognized jurisdiction that encompasses the area of future growth around Virginia’s capital, the City of Richmond, for which geological mapping will be most beneficial.

The Richmond MSA straddles the Piedmont and Coastal Plain provinces. It is situated at the intersection of four major interstates: I-95, I-295, I-64, and I-85 (Figure 1). This area is home to approximately one in seven of Virginia’s citizens, contains nearly every type of business and industry, and is home to major military installations, including Fort Lee, which is the headquarters of the U.S. Army’s Combined Arms Support Command, Quartermaster School, and Ordnance School. Outside of developing areas, agriculture is a stable part of the economy, with approximately 4,300 farms on nearly 900,000 acres (U.S. Department of Agriculture, 2007). This area encompasses all or a portion of six regional planning districts.

DGMR and the GMAC have ranked the 95 unpublished 7.5-minute quadrangles that are substantially within the Richmond MSA either a high or low priority. This ranking is based upon societal needs identified by the respective planning districts or other government agencies and the potential for mineral resources or geologic hazards. Quadrangles that are assigned a high priority ranking meet one or more of the following criteria:

- Significant change in land use, including urban and suburban development, is anticipated;
- High potential for mineral resources;
- Known geologic hazards exist;
- Population center or highly developed area;
- Situated along an Interstate;
- Within the epicentral area for the August 23, 2011 magnitude 5.8 earthquake centered in Louisa County (added at 2012 GMAC meeting)

The long-term goal of this project is to complete 1:24,000-scale geologic mapping of all remaining quadrangles in the MSA that are identified as high priority (Figure 7). An ultimate goal is to use this data in combination with existing data on the low-priority quadrangles to create a 1:100,000-scale geologic map of the entire MSA. Intermediate products for this study will be 1:24,000-scale geologic maps of single or multiple quadrangles, to be published in paper or digital form, and a series of open-file reports on CD and the internet that contain GIS files for the current extent of the geologic compilation.

Location and Geologic Setting

The Richmond MSA encompasses 16 counties in the Piedmont and Coastal Plain of Southeast Virginia. The cities of Richmond, Petersburg, Colonial Heights, and Hopewell are located along interstates I-95, I-64, I-85, and I-295. Several major U.S. Highways connect these cities with smaller communities both inside and outside of the MSA. The region contains significant portions of three river basins; from north to south they are the York, James, and Chowan. The lower portions of the York and James rivers flow through the area and into the Chesapeake Bay. Several smaller rivers form the headwaters of the Chowan River and become part of the Albemarle-Pamlico watershed. The Chesapeake Bay and the lower reaches of the Albemarle-Pamlico watershed represent the largest and second largest estuarine systems in the United States, respectively.

The western half of the Richmond MSA is located in the Piedmont physiographic province. Crystalline rocks in the Piedmont portion of the MSA are assigned to three separate tectonic terranes. From west to east they are the Chopawamsic terrane, the Goochland terrane, and the Southeastern Piedmont terrane. The Chopawamsic terrane contains metavolcanic, metaplutonic and metasedimentary rocks that are believed to have formed in a middle to late Ordovician-age volcanic arc (Coler and others, 2000). The Goochland terrane is composed of multiply-deformed igneous rocks and metamorphic rocks of uncertain affinity. At least a portion of the Goochland terrane is Mesoproterozoic in age. The Goochland terrane is separated from the Chopawamsic terrane by the Spotsylvania fault and is separated from the Southeastern Piedmont terrane by the Hylas fault (Spears and others, 2004). The Southeastern Piedmont terrane contains a variety of metamorphic rocks, some of which appear to have volcanic protoliths. The late Paleozoic-age Petersburg Granite intrudes a substantial portion of the Southeastern Piedmont terrane in the project area. Another portion is unconformably overlain by Mesozoic-age sedimentary rocks of the Richmond and Taylorsville basins, which were deposited in a series of half-grabens. Both of these basins have had historic coal production and oil and gas exploration.

The central part of the Richmond MSA lies within the Fall Zone. In this complex zone, Coastal Plain sediments overlie rocks of the eastern Piedmont, and both sediment and bedrock are exposed and mappable. Much of the eastern part of the Richmond MSA is within the Coastal Plain. Cretaceous through Holocene sediments in the Coastal Plain form an eastward-thickening wedge as much as 1,000 feet thick in the project area. These sediments overlie Precambrian to Mesozoic rocks. Estuarine and fluvial sediments of Miocene-Pliocene age cap the higher elevations and become thicker to the east.

Purpose and Justification

Water Resource Location

The City of Richmond and nearby counties of Henrico and Chesterfield in the Richmond MSA obtain their water supplies from surface sources, including the James River. Most other public and private water supplies in the MSA are groundwater-based. Recharge areas for major Coastal Plain aquifers, such as the Potomac Aquifer, are present in the area. Mapping in the areas where these units crop out is providing an opportunity to better understand the characteristics of these important units.

Shallow wells in the Coastal Plain are vulnerable to surface contamination from point and non-point sources. In fractured crystalline rock aquifers, well yields are unpredictable, although supplies are typically adequate for residential use. Higher yield supplies for industries and municipalities are more difficult to locate. Detailed geologic mapping will also provide useful information to municipalities, businesses, and industries when siting reservoirs and water supply wells.

Economic Product Development

The Richmond Metropolitan Statistical Area (MSA) currently contains 89 active mine and quarry operations that produce economically significant quantities of crushed stone, clay, sand, gravel, and industrial minerals. These construction materials are in high demand to support growth in the area. Industrial minerals including feldspar, vermiculite, and fuller's earth are exported from the Richmond area, providing business income and local jobs. Titanium-bearing minerals and zircon are currently being produced from a nationally significant heavy mineral sand mine in the southern part of the MSA.

Past mineral production in the Richmond MSA includes many commodities not currently being produced, but which may have potential for redevelopment in the future. Coal from the Mesozoic Richmond Basin was produced locally for over two hundred years; while it's not likely that coal mining will return to Richmond, deep coal deposits have been explored in recent years for coal bed methane. Building and dimension stone played a significant role in the growth and development of the City of Richmond until the 1940s. Gold, sulfide minerals, and mica were produced in the past and may still be present in significant quantities (Spears and Upchurch, 1997). Improvements in technology or changes in demand may make some of these commodities economically viable in the future. Detailed geologic maps will be critical for the evaluation and development of these resources.

Geologic Hazard Identification

Known geologic hazards in the Richmond MSA include earthquakes, acidic soils, shrink-swell soils, subsidence in the vicinity of abandoned underground mines, flooding, slope stability, and unsafe levels of radon and other potentially hazardous naturally occurring elements in soil and ground water. The western part of the Richmond MSA is within the Central Virginia Seismic Zone. Small magnitude earthquakes within this area are common, occurring every year or two. The frequency of larger earthquakes such as the August 23, 2011 magnitude 5.8 earthquake centered in Louisa County is entirely unknown.

In light of the recent earthquake, a better understanding of the location and attitude of faults in the western part of the Richmond MSA is clearly needed. A lack of detailed geologic mapping and sparse seismic monitoring in the epicentral region delayed the identification of damaged areas and made it impossible for local emergency workers to proactively check on citizens at greatest risk for injury. Critical infrastructure within the Central Virginia Seismic Zone includes a nuclear power plant, a coal-fired power plant, two natural gas-fired power plants, and eight state prisons. Understanding the relationship of these facilities to potentially active faults will enable better emergency response in the future.

Surface collapses in the vicinity of historic coal mines in the Richmond basin have been a significant problem in recent years because of residential and commercial development in former coal mining areas. Since most of these mines were abandoned in the 1800s, their exact locations and extents are often unknown. Our geologic maps provide geologic constraints to help reclamation inspectors target their search.

Acidic soils associated with the Eastover Formation (Miocene lower Chesapeake Group) are widespread in the eastern portion of the Richmond MSA. Water discharging from these soils can have a pH as low as 2 or 3, contributing to habitat degradation in streams and the premature failure of concrete and steel structures. The remnants of tropical depression Gaston in 2004 caused severe flooding and numerous landslides in downtown Richmond and vicinity.

Natural Resource Protection

Developmental pressures within the Richmond MSA are causing changes in land use. During development, open space is converted to industrial, commercial, and residential use. These changes have both positive and negative effects on the region's natural resources. In many cases, the geology can play an important role in the nature and extent of these impacts. Detailed geologic maps will provide useful information to land-use planners, natural resource caretakers, and environmental consultants who work in the MSA. The Petersburg and Richmond National Battlefields are located in the Richmond MSA and the National Park Service has expressed interest in geologic mapping of these properties and surrounding areas to support park management.

Water contamination is a significant problem in many parts of Richmond MSA. Water quality in the region is impacted by a number of pollution sources, including industrial sites, contaminated runoff and excessive sedimentation. Non-point and point source pollution in developing areas also contributes fertilizers, pesticides, petroleum products, solvents, and other chemicals to streams and aquifers. Development often results in greater areas of impervious surfaces, resulting in increased surface overland flow into streams. Approximately 36 percent of monitored streams and rivers in the York River Basin and 23 percent in the James River Basin are not supporting designated uses that include providing aquatic or wildlife habitat, fish or shellfish for consumption, public water supply, or outdoor recreation (Virginia Department of

Environmental Quality, 2008). Water discharging from these rivers affects water quality in the Chesapeake Bay, which was listed among the southeast's "Top 10 Endangered Places" in 2012. Monitoring suggests that 50 percent of the Chesapeake Bay is degraded (Virginia Department of Environmental Quality, 2008).

Facility Siting

As development in the region continues, additional major facilities such as solid and liquid waste disposal facilities will need to be constructed. These include municipal landfills, wastewater treatment plants, and land application sites. In addition, the North Anna Nuclear power station is seeking to expand its power generation capacity. Geologic conditions such as the thickness and texture of regolith, the spacing and orientation of fractures and planar fabrics, the location and character of fault surfaces, and the susceptibility to earthquakes can be important to consider when situating, designing, and monitoring these types of facilities. Detailed geologic maps will provide useful information to the decision makers.

Roads and Infrastructure Development

Several major highway construction projects are underway or are being planned in the region, including the expansion and realignment of U.S. Highway 460 and the widening of I-64 east of Richmond. Detailed geologic maps will provide useful information to the Virginia Department of Transportation, municipal and private utilities, and private and public land developers.

Science Issues

One research goal of this project is deciphering the potentially complex metamorphic history of the Petersburg Granite. Although traditionally portrayed as a single, homogenous pluton (e.g., Calver and others, 1963), detailed mapping in the Richmond area demonstrates that the granite can be subdivided into four phases, following the earlier work of Bobyarchick (1978), and challenges the relevance of a single geochronometric date for the entire outcrop belt (i.e., Wright and others, 1975).

In the Coastal Plain, the Bacons Castle Formation (Coch, 1965) and Chesapeake Group (Ward and Blackwelder, 1980) have been extended from the outer Coastal Plain subprovince, following Mixon and others (1989), to the Inner Coastal Plain in the Richmond area at 1:24,000-scale. Researchers can now begin to expand the Chesapeake Group into recognized formal lithostratigraphic units, based primarily on detailed paleontologic and stratigraphic studies. In addition, our detailed maps and borehole database in the Coastal Plain allow for the construction of derivative isopach maps, which will enable paleogeographic interpretations of sea level fluctuations and syndepositional tectonics from the Cretaceous to the Holocene in the Richmond area. We are also identifying younger structures that offset Coastal Plain units. These faults may play a significant role in ground water transport, and are described in more detail in the Preliminary Results section.

Strategy for Performing Geologic Mapping

Most 7.5-minute quadrangles in the Richmond MSA have geologic coverage that falls into one of three categories: published mapping at 1:24,000 scale; unpublished or published mapping at a scale between 1:24,000 and 1:250,000; and mapping at a scale of less than 1:250,000 (Figure 4). Our strategy is to compile existing blocks of published 1:24,000-scale maps and bring the level of mapping in high priority quadrangles up to 1:24,000-scale quality. Geologic compilation will be continually expanded as new quadrangles are mapped.

Mapping will be carried out by experienced field geologists as listed in the personnel section. Field observations will be collected using Trimble Nomad GPS data loggers. Lithologic descriptions, bedding orientation, and other geologic observations will be recorded and stored with GPS coordinates in ESRI shapefile format. The shapefiles will then be uploaded to ArcMap 10.1 in the office, where the point data will be overlain on digital topographic maps and digital terrain models. The geologist will then draw the geologic map directly in ArcMap. All map features will be stored with feature-level metadata in NCGMP09 geodatabase format.

Quadrangles will be prioritized to include areas:

- where new geologic mapping is needed to address an important natural hazard, environmental, development, or natural resource issue;
- adjacent to previously compiled geologic maps;
- where existing geologic mapping is nearly 1:24,000-scale quality.

This project requires mapping approximately 45 7.5-minute quadrangles (Figure 7). Unpublished data existed for many of these quadrangles, but only seven were published at a scale of greater than 1:250,000 at the time the project began. The final product will involve the compilation of these maps and 13 previously published quadrangles. It is anticipated that the Richmond MSA geologic mapping project could be completed in approximately ten years with adequate staff and funding. For 2014-2015, we propose the following projects:

1. New Geologic Mapping (2.5 quadrangles)

This project will build upon our 2005 - 2013 STATEMAP geologic mapping effort, consisting of 12 7.5-minute quadrangles. Detailed 1:24,000-scale mapping of the Manquin, Perkinsville (½),South Anna (½), and Zions Crossroads (½) quadrangles is proposed (Figure 7; Table 2). The Perkinsville and South Anna quadrangles are high priority because they are situated along I-64 in developing areas to the west of Richmond. The South Anna quadrangle is also within the epicentral region for the August 23, 2011 earthquake. The Zion Crossroads quadrangle, situated between Charlottesville and Richmond, has seen rapid commercial, residential, and industrial development during the past few years. Water resources have been an issue in this area, and new mapping will help identify additional resources as development continues. The Manquin quadrangle is in a developing area northeast of Richmond and along U.S. 360, a major transportation route. The proposed mapping in the Perkinsville and South Anna areas, when combined with ongoing work, will result in two complete geologic maps. Mapping in Manquin will extend revised coastal plain stratigraphic nomenclature from recently mapped Quinton quadrangle towards the north.

As part of the mapping program, samples that are typical of significant map units will be collected. A portion of these samples will be submitted for whole rock chemical analysis. A second portion of consolidated rocks will be used to make thin sections. A third portion of consolidated rocks will be placed into our rock repository. Whole rock analyses will include major, minor, trace, and rare earth elements. The analytical results will be used to correlate rock types and identify potential mineral resources. The results will be compiled into a database that is available to the public. This database can be used to identify the background concentrations of metals such as arsenic, barium, cadmium, chromium, lead, and mercury that are routinely detected in soil and ground water during environmental investigations. Samples may also be collected and analyzed for heavy minerals.

In 2012, DMME began collecting samples at selected locations for exposure or burial age dating based on cosmogenic radionuclide concentrations. Deposits targeted to date include terrace and debris-flow deposits of unknown age. Having absolute age ranges for these deposits will improve our ability to make accurate surficial maps and

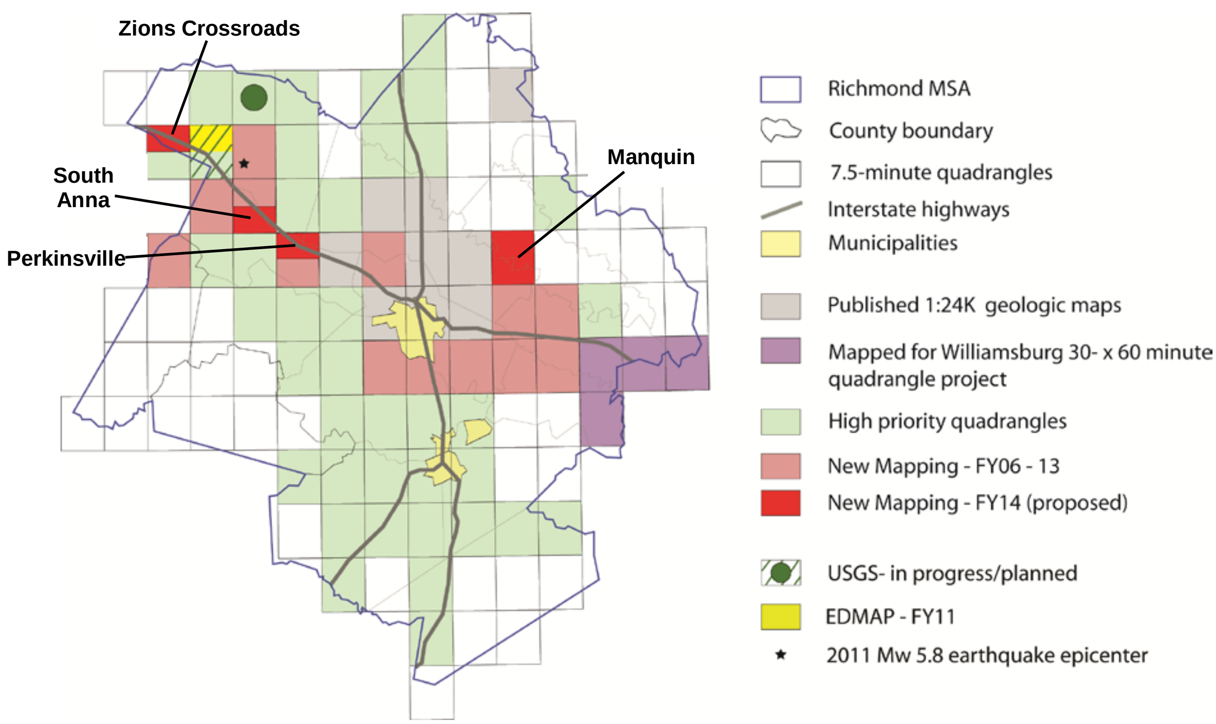

Figure 7. 7.5-minute quadrangles proposed for new mapping within the Richmond MSA project area. FY = Federal fiscal year.

improve our understanding of the frequency of alluvial and colluvial processes. Three samples are proposed in the Richmond MSA project area, with the sample locations to be determined after mapping is underway. Age dating of surficial deposits will be done in conjunction with Greg Hancock at the College of William and Mary. We would also like to collect a single sample for SHRIMP U-Pb zircon dating from a sample in the Pendleton or South Anna quadrangle to help establish better relationships among Piedmont rock units. The sample location will be determined after mapping is underway to provide greatest benefit. This analysis will be done in conjunction with Texas A&M or another university to be determined.

2. Remapping and GIS compilation of existing quadrangles (1.5 quadrangles)

This project will build upon our 2005 - 2013 STATEMAP geologic compilation, consisting of 9.5 7.5-minute quadrangles. This year we propose to add the Hylas quadrangle and the remaining half of the Yellow Tavern quadrangle (Figure 8; Table 2). The Hylas quadrangle was mapped by Goodwin (1970). Yellow Tavern quadrangle was mapped by Daniels and Onuschak (1974). Significant remapping is needed in both quadrangles, due to changes in stratigraphic nomenclature, the existence of new exposures resulting from development, and the need to correlate the geology in these areas with more recently mapped quadrangles. Field checking is also needed in areas of new exposure, areas where stratigraphic and structural inconsistencies exist, and along quadrangle boundaries.

The digital compilation of these quadrangles will utilize the new standard format for geologic map publications developed by the National Cooperative Geologic Mapping Program of the USGS (NCGMP09 standard database schema). This compilation will be an ESRI geodatabase that will include the principal map view, cross-sections, FGDC Digital Cartographic Standard symbology, feature-level metadata, standard lithology descriptions, geochemistry data, reference glossary, and data sources. We also intend to use these updated files to make publishable maps of all three quadrangles.

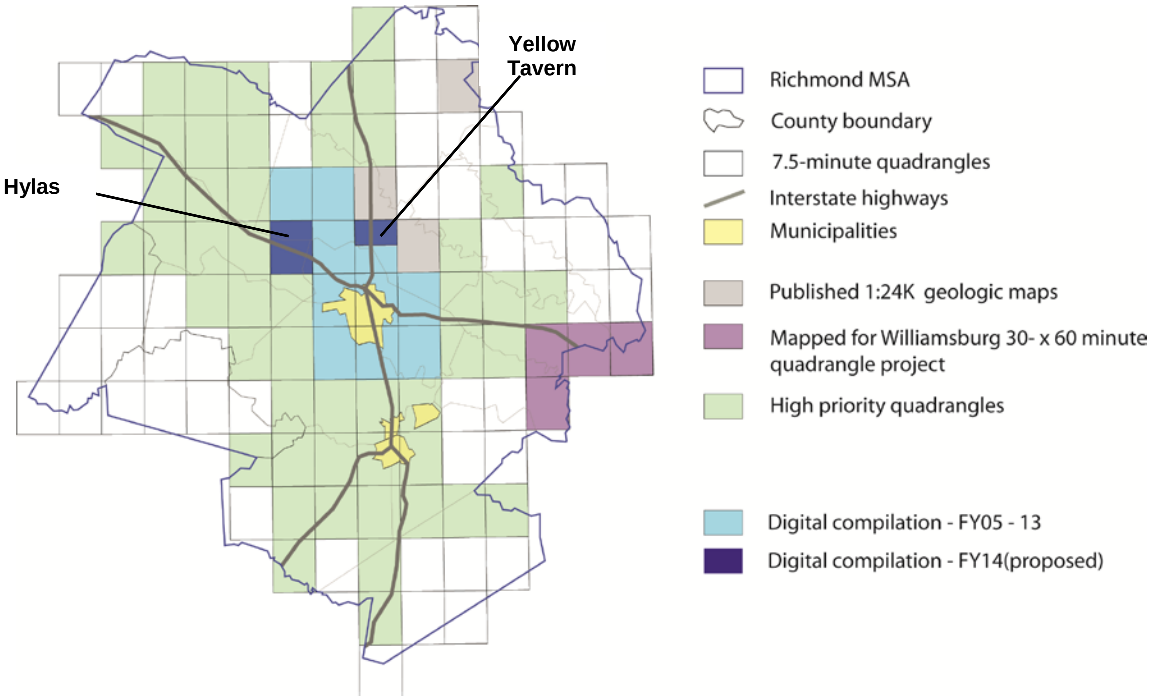

Figure 8. 7.5-minute quadrangles proposed for Remapping and GIS compilation within The Richmond MSA project area. FY = Federal fiscal year.

Table 2. Summary information for proposed Richmond MSA projects.

Project	Existing information		Geologic issues			Area factors		Estimated field days	Average cost per quad
	Contacts	Data Density	Stratigraphic	Structural	Boundary	Complexity	Access		
New Mapping									
Manquin	1:250,000 published	Poor	Yes	Yes	No	Moderate	Fair	60	$88,005
Perkinsville (1/2)	1:100:000 published	Poor	Yes	Yes	No	High	Fair	30	
South Anna (1/2)	1:500,000 published	Poor	Yes	Yes	Yes	High	Fair	30	
Zions Crossroads (1/2)	1:500,000 published	Poor	Yes	Yes	Yes	High	Fair	30	
Remapping									
Hylas	1:24,000 published	Poor	Yes	Yes	Yes	High	Fair	50	$63,153
Yellow Tavern (1/2)	1:24,000 published	Poor	Yes	Yes	Yes	Moderate	Fair	25	

Preliminary Results and Previous Work

Preliminary Results

We are in our ninth year of compiling new and existing geologic maps in the Richmond MSA. In our first two years, we significantly updated and re-mapped previously published geologic maps of the Richmond, Bon Air, and Seven Pines 7.5-minute quadrangles and began new mapping on the Chesterfield and Drewry's Bluff 7.5-minute quadrangles. We subsequently completed mapping the Chesterfield, Drewry's Bluff, Dutch Gap, Glen Allen, Providence Forge, Roxbury, and Tunstall quadrangles. We recently completed mapping the Pendleton quadrangle, and are currently completing the Quinton quadrangle and initiating mapping on the Perkinsville and South Anna quadrangles. This work has significantly increased our understanding of inner Coastal Plain and Southeastern Piedmont stratigraphy, structure, and geomorphic evolution in several areas:

Characterization of the Petersburg granite

Previous geologic maps (Daniels and Onuschak, 1974; Goodwin, 1980, 1981) grossly subdivided the Mississippian Petersburg Granite into two units in this area: uniform textured granite, and porphyritic granodiorite. We have more recently been able to delineate four phases of Petersburg Granite intrusion: early phases consisting of layered granite gneiss and well-foliated granite, a fine- to coarse-grained subidiomorphic middle phase, and a late phase of coarse porphyritic granite in map-scale screens and discrete zones. Within these phases, we are also recognizing map-scale xenoliths of biotite gneiss and schist, and mafic and altered ultramafic rocks.

Mineral resources

Coastal Plain stratigraphy has been significantly refined in the years since publication of the original quadrangles in this area. For instance, we now recognize that Pliocene Yorktown Formation (upper Chesapeake Group) and Pliocene-Pleistocene Bacons Castle Formation lithologies extend westward into the inner Coastal Plain (e.g., Mixon and others, 1989). Our new mapping demonstrates that sand and gravel of the Bacons Castle Formation underlies vast areas of the Richmond and Seven Pines quadrangles between the Chickahominy and James rivers, and is a virtually untouched source of aggregate in this increasingly urbanized region. Additionally, we have recognized internal stratigraphy within the near-shore facies of the Yorktown Formation in the Richmond area. South of Petersburg, similar Yorktown lithofacies hold the largest deposits of heavy minerals in the eastern U.S. Continued detailed mapping in the Richmond area has shown high abundance of heavy minerals in places, and may reveal additional resources such as phosphate.

Cenozoic faulting

Mapping in the Dutch Gap and Providence Forge quadrangles has identified two previously unknown, regionally significant structures, the Dutch Gap and Providence Forge faults. The Dutch Gap fault is located beneath Bacons Castle sediments. Exposure of the fault is concealed by colluvium and alluvium. This down-to-the-west fault likely affects recharge and transmission of ground water in the Cretaceous

Potomac Formation, an important regional aquifer. The fault was traced into the Drewry's Bluff quadrangle and extends into the Richmond quadrangle. The Providence Forge fault is a north- to south-trending structure that exhibits down-to-the-east normal movement with approximately 125 feet of throw. Based on stratigraphic relationships, movement on the fault appears to be syndepositional with the Yorktown Formation. The fault overlies strong gravity and magnetic gradients suggesting a buried Mesozoic basin may lie to the east. While mapping the Roxbury quadrangle this past year, we discovered another previously unknown fault, the Malvern Hill Fault. It is also north-trending with down-to-the-east movement, but the throw ranges from 20 to 40 feet. This fault has been mapped northward into the Quinton quadrangle and appears to continue into the Manquin quadrangle.

River Channel sediment mapping

A recent addition to the Richmond MSA and the Williamsburg projects includes mapping the sediments in the bottom of the James, Chickahominy, and other rivers within project quadrangles. Sidescan sonar is being used in conjunction with bottom sampling to identify scoured, muddy, and sandy to cobbly river bottoms. This mapping has benefited habitat studies (sturgeon and oyster habitat restoration, for example) and located potential sand and gravel deposits.

Epicentral area of the Mineral, Virginia Earthquake of August 23, 2011

Following the August 2011 Magnitude 5.8 Earthquake in Louisa County, Virginia, the GMAC made the epicentral area a high priority for detailed geologic mapping. Many homes in the epicentral area sustained significant damage, and two county school buildings were deemed unrepairable and had to be demolished. The epicentral area fell within the Richmond MSA, so the shift in priority did not represent a major change in DGMR's long-range mapping plan. Mapping was completed on the Pendleton quadrangle, which contains the epicenter, in 2013. This mapping revealed a structurally complex area in the vicinity of the epicenter, and identified at least one previously-unknown Paleozoic-age fault. We have also been working closely with Bill Burton and Rich Harrison at the USGS, who are mapping in the adjacent Ferncliff quadrangle. Other collaborators include USGS geophysicists interpreting detailed geophysical data collected after the earthquake and Lehigh University researchers analyzing fluvial terrace deposits for evidence of neotectonic vertical displacement.

Previous Work

David Spears collected limited reconnaissance data on the South Anna quadrangle as part of DGMR's response to the earthquake in 2011-2012. The Perkinsville quadrangle was previously mapped at 1:100,000-scale (Marr, 2002). No published mapping beyond the 1:250,000-scale geologic map of the Virginia Coastal Plain (Mixon and others, 1989) is available for the Manquin quadrangle. No published mapping beyond the 1:500,000-scale Geologic Map of Virginia (Virginia Division of Mineral Resources, 1993) is available for the Zion Crossroads. The Yellow Tavern quadrangle was originally mapped by Daniels and Onuschak (1974); Mark Carter remapped the southwest quarter of Yellow Tavern in 2008-2009 through the STATEMAP program. The Hylas quadrangle was originally mapped by Goodwin (1970).

Deliverable Geologic Maps

The deliverables for this project will be:

1. Geologic map and cross-section of the Manquin quadrangle;
2. Geologic map and cross-section of half of the Perkinsville quadrangle;
3. Geologic map and cross-section of the half of the South Anna quadrangle;
4. Geologic map and cross-section of the half of the Zions Crossroads quadrangle;
5. Digitally compiled geology as GIS files for the Hylas and Yellow Tavern quadrangles (a paper copy of each quadrangle will also be provided).

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SUMMARY OF PREVIOUS STATEMAP PRODUCTVITY

Our 2013 STATEMAP project ($177,965 federal funding) consists of geologic mapping of all or portions of six quadrangles: Glenvar, Perkinsville, Quinton, Rileyville, South Anna, and Timberville; digital compilation of all or portions of three quadrangles: Pilot, Woodstock, and Yellow Tavern.

Our 2012 STATEMAP project ($192,767 federal funding) consists of geologic mapping of all or portions of six quadrangles: Caledonia, Glenvar, Pendleton, Quinton, Rileyville, and Timberville; digital compilation of all or portions of four quadrangles: Montpelier, Riner, Pulaski, and Toms Brook; and digital compilation of the eastern part of the Williamsburg 30- x 60-minute quadrangle.

Our 2011 STATEMAP project ($216,572 federal funding) consisted of geologic mapping of all or portions of seven quadrangles: Big Levels, Caledonia, Cape Charles, Collierstown, Elliott Creek, Ironto, and Tunstall; digital compilation of all or portions of three quadrangles: Blacksburg, Hanover Academy, and White Gate; and digital compilation of the western part of the Williamsburg 30- x 60-minute quadrangle.

Our 2010 STATEMAP project ($207,815 federal funding) consisted of geologic mapping of all or portions of seven quadrangles: Broadway, Claremont, Cornwall, Dendron, Ironto, Luray, New Market, and Roxbury; and digital compilation of all or portions of five quadrangles: Chesterfield, Drewry's Bluff, Dutch Gap, Edinburg, and Glen Allen.

Our 2009 STATEMAP project ($176,410 federal funding) consisted of geologic mapping of all or portions of seven quadrangles: Beach, Claremont, Cornwall, Dendron, Montebello, Providence Forge, and Runnymeade; and digital compilation of all or portions of three quadrangles: Dublin, Elkton West, and Radford South.

Our 2008 STATEMAP project ($217,989 federal funding) consisted of geologic mapping of all or portions of nine quadrangles: Broadford, Cedar Springs, Collierstown, Cornwall, Dutch Gap, Elliston, Glen Allen, Stanley, and Surry; and digital compilation of all or portions of three quadrangles: Atkins, Goshen, and Vesuvius.

Our 2007 STATEMAP project ($215,340 federal funding) consisted of geologic mapping of all or portions of eleven quadrangles: Atkins, Broadford, Chesterfield, Drewry's Bluff, Dutch Gap, Elkton West, Elliston, Goshen, Montebello, Stanley, and Walkers; and digital compilation of all or portions of six quadrangles: Augusta Springs, Bent Mountain, Conicville, Edinburg, Redwood, and Saltville.

Our 2006 STATEMAP project ($209,354 federal funding) consisted of geologic mapping of all or portions of nine quadrangles: Atkins, Augusta Springs, Bent Mountain, Chesterfield, Claremont, Drewry's Bluff, Gloucester, Saltville, and Surry; and digital compilation of all or portions of ten quadrangles: Bon Air, Boones Mill, Brownsburg, Garden City, Hardy, Lexington, Radford North, Redwood, Seven Pines, and Staffordsville.

Our 2005 STATEMAP project ($227,186 federal funding) consisted of geologic mapping of all or a portion of seven quadrangles: Gloucester, Lexington, Marion, Redwood, Saltville, Vesuvius, and Ware Neck; a surficial geologic map of the northern half of the Grottoes quadrangle; and a geologic and digital compilation of all or portions of five quadrangles: Arnold Valley, Bon Air, Buchanan, Natural Bridge, Richmond and Seven Pines.

Our 2004 STATEMAP project ($171,151 federal funding) consisted of geologic mapping of the Boones Mill, Garden City, Hamburg, and Hardy quadrangles; a surficial geologic map of the northern half of the Grottoes quadrangle; and a geologic and digital compilation of four 1:24,000 quadrangles: Crimora, Parnassus, Waynesboro East, and Waynesboro West.

Our 2003 STATEMAP project ($95,955 federal funding) consisted of a geologic and digital compilation of eleven 1:24,000 quadrangles: Bridgewater, Broadway, Fort Defiance, Greenville, Grottoes, Harrisonburg, Mt. Sidney, New Market, Staunton, Stuarts Draft, and Tenth Legion.

Our 2002 STATEMAP project ($31,000 federal funding) consisted of mapping portions of five 1:24,000 quadrangles: Hayters Gap, Glade Spring, Chilhowie, Damascus, and the Virginia portion of Laurel Bloomery.

Our 2001 STATEMAP project ($14,899, federal funding) consisted of mapping three 1:24,000 quadrangles in the Virginia coastal plain (Mathews, Achilles, and New Point Comfort).