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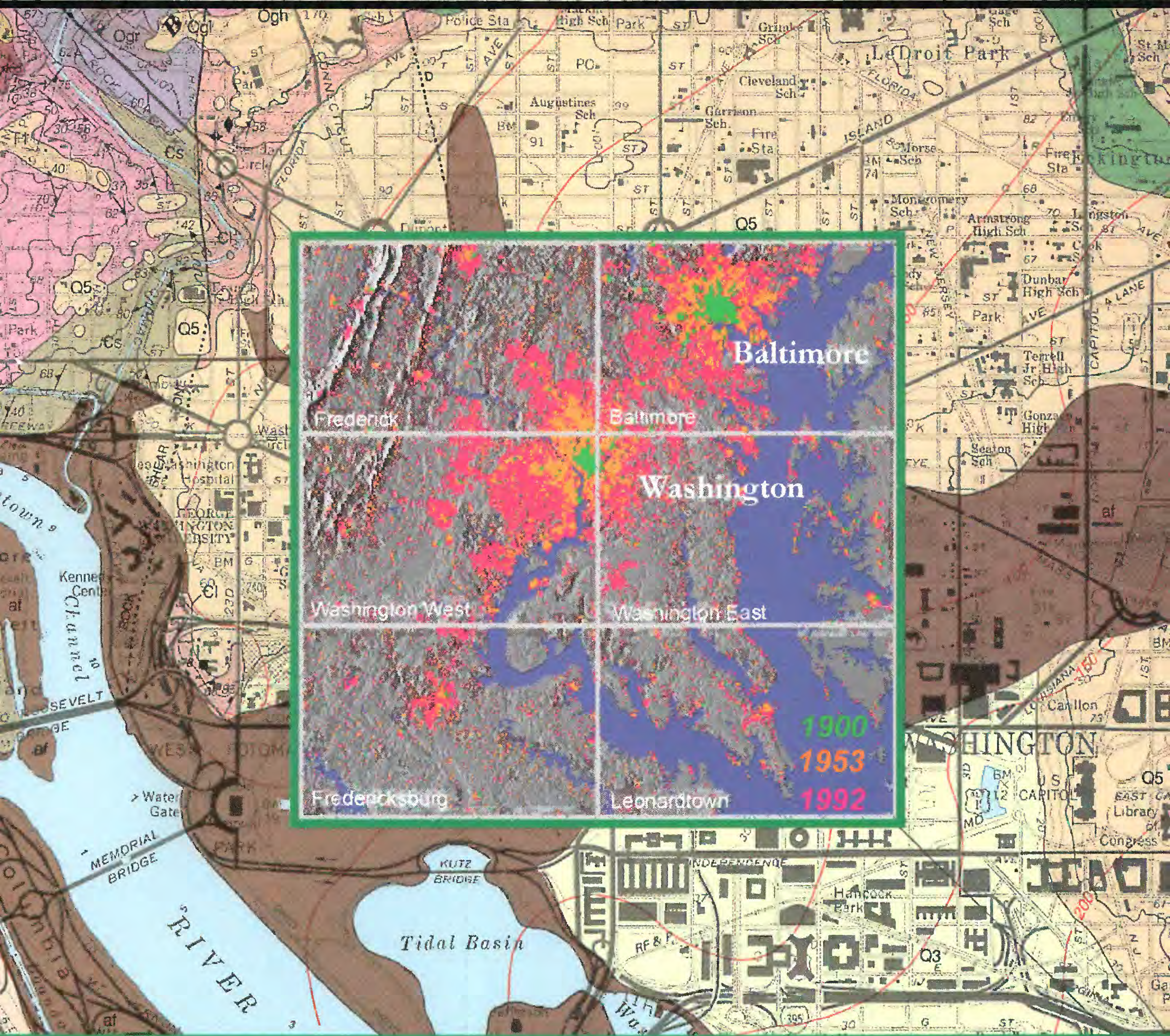
Forum on Geologic Mapping Applications in the Washington–Baltimore Urban Area

U.S. GEOLOGICAL SURVEY CIRCULAR 1148



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Cover.
Background.—Image from the geologic map of the Washington West quadrangle, District of Columbia, Montgomery County and Prince Georges Counties, Maryland, and Arlington and Fairfax Counties, Virginia, by A.H. Fleming and others (1994, U.S. Geological Survey Map GQ–1748, scale 1:24,000).
Inset.—Areas of 30′ × 60′ quadrangle geologic mapping in relation to stages of urban growth from the year 1900 (green) to 1953 (orange) and 1992 (red), adapted from urban growth maps produced by the U.S. Geological Survey Mapping Applications Center in cooperation with the University of Maryland Baltimore County, the U.S. Bureau of Census, and others. Further information is available on the World Wide Web at http://edcwww.cr.usgs.gov/umap/umap.html. Computer graphics by Stephen Schindler and Lendell Keaton.

Forum on Geologic Mapping Applications in the Washington-Baltimore Urban Area

PROCEEDINGS

RESTON, VIRGINIA
APRIL 23, 1997

Edited by J. Wright Horton, Jr., U.S. Geological Survey, and
Emery T. Cleaves, Maryland Geological Survey

U.S. GEOLOGICAL SURVEY CIRCULAR 1148

Sponsored by the
U.S. Geological Survey and the
Maryland Geological Survey

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1997

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
MARK SCHAEFER, Interim Director

Free on application to the U.S. Geological Survey, Information Services
Box 25286, Federal Center, Denver, CO 80225

Published in the Eastern Region, Reston, Va.
Manuscript approved for publication September 2, 1997.

Library of Congress Cataloging in Publication Data

Forum on Geologic Mapping Applications in the Washington-Baltimore Urban Area (1997 : Reston, Va.)
Forum on Geologic Mapping Applications in the Washington-Baltimore Urban Area : proceedings, Reston, Virginia, April 23, 1997 / edited by J. Wright Horton and Emery T. Cleaves.
p. cm. — (U.S. Geological Survey circular ; 1148)
"Sponsored by the U.S. Geological Survey and the Maryland Geological Survey."
Includes bibliographical references.
1. Geological mapping—Washington (D.C.) Region —Congresses. 2. Geological mapping—Maryland—Baltimore Region—Congresses. I. Horton, J. Wright. II. Cleaves, Emery T. III. Geological Survey (U.S.) IV. Maryland Geological Survey. V. Title. VI. Series.
QE36.F615 1997
557.5'022'3—dc21 97–38788
CIP

PURPOSE

The Forum on Geologic Mapping Applications in the Washington-Baltimore Urban Area was convened on April 23, 1997, at Reston, Va. The forum was cosponsored by the U.S. Geological Survey (USGS) and Maryland Geological Survey (MGS), with assistance from the Virginia Division of Mineral Resources. It was convened by Wright Horton (USGS) and Emery Cleaves (MGS).

Urban areas are dynamic systems that interact with the environment through consumption of resources, production of wastes and pollutants, and modification of watersheds. Spatial earth science information in the Washington-Baltimore area provides a scientific framework for environmental assessment, urban planning, and future resource and hazard investigations in this area of the Chesapeake Bay watershed, which has sustained three centuries of urban growth.

<u>The goals of the forum were to</u>—

- Promote communication between users and providers of geologic maps and related earth science information.
- Encourage user input and partnerships in the design of geologic mapping activities and products.

<u>The forum was organized into six sections</u>—

- Introductory perspectives.
- Panel discussions focusing on four areas—urbanization and water quality, creating durable habitats, geologic information for the urban system, and natural and induced hazards—avoidance and remediation.
- Poster session displays—Geologic maps and applications.
- Reviews of statewide geologic information user surveys in Maryland and Virginia.
- Focus group discussions and recommendations on four topics—ecosystems and water resources, geotechnical applications, resources essential for the urban system, and optimal land use.
- Wrap-up session.

ACKNOWLEDGMENTS

We would like to thank Stan Johnson (State Geologist, Virginia Division of Mineral Resources) for his assistance in organizing this forum. The forum also benefited from the strong support and encouragement of John Pallister (Coordinator, National Cooperative Geologic Mapping Program) and James Quick (Chief Scientist, U.S. Geological Survey (USGS), Eastern Region National Cooperative Geologic Mapping Team). James Gerhart (USGS, State Representative and Maryland-Delaware-District of Columbia District Chief, Water Resources Division) and Gilpin Robinson (Project Chief, Mid-Atlantic Geology and Infrastructure Case Study, USGS Eastern Mineral Resources Team) provided helpful information and advice. The meeting facilitators, Berwyn Jones, Lyn Dellinger, Jonathan Dillow, and Dennis VanLiere led the focus groups and assured the production of a useful report under tight time constraints. Wayne Newell, Peter Lyttle, Lucy McCartan, and John Peper helped with the design of the program, with Newell and Lyttle incorporating lessons from their experience with a recent geologic mapping forum in Indiana. Lyttle also helped with arrangements for facilities and publicity and served as recorder. Lucy McCartan and Steve Schindler deserve credit for computer graphics and the design of brochures, registration packets, and posters. Chris Flynt and Loretta Morris (registration process, mailing lists, and transcriptions), Jack Epstein (photography), Scott Southworth (poster session), and many others helped to maintain high standards and attention to detail under pressing deadlines, contributing to the smooth operation and ultimate success of the forum. Finally, we thank all of the speakers, panelists, poster presenters, and focus-group participants for their roles in articulating the multiple needs for geologic map information in the Washington-Baltimore urban area.

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FORUM ON
GEOLOGIC MAPPING APPLICATIONS IN THE WASHINGTON-BALTIMORE URBAN AREA

J. Wright Horton, Jr., and Emery T. Cleaves, editors

INTRODUCTORY REMARKS

Leveraging Earth Science Resources

John S. Pallister, Coordinator, and
Peter T. Lyttle, Associate Coordinator
National Cooperative Geologic Mapping Program
Geologic Division, U.S. Geological Survey

The production of geologic maps around the world has undergone dramatic change during the last decade. Several trends have been driving this change—the shrinking budgets of most geological surveys (which require partnerships for most efficient use of resources), the continued high costs for publication of traditional color geologic maps, and the realization that geologic maps are integral parts of multidisciplinary geographic information systems (GIS's) that are used by decisionmakers at the local, State, and National levels.

Recently, the National Cooperative Geologic Mapping Program (NCGMP) sponsored geologic mapping forums and workshops in each region of the country to promote communication between the users and providers of geologic maps and related earth science information and to assess regional needs for geologic map information. By encouraging user input and partnerships in the design of geologic mapping products, the U.S. Geological Survey (USGS) and State Geological Surveys hope to enhance the usefulness of their geologic maps and to use their funds more effectively.

This Forum on Geologic Mapping Applications in the Washington-Baltimore Urban Area, hosted by the USGS and Maryland Geological Survey with assistance from the Virginia Division of Mineral Resources, is the first attempt at obtaining a direct assessment of the needs of the Mid-Atlantic geologic map user community. In effect, for much of the discussion, the USGS and the State Surveys are here "to listen" to clients. By including over 130 participants from private industry as well as local, State, and Federal Government Agencies, and universities, NCGMP will be able to hear the opinions of important users of geologic map data and to determine ways to better leverage our earth science resources.

In addition to sharpening the focus of geologic mapping in the Washington-Baltimore urban area, the forum will contribute to the evolving plans and goals of the National Cooperative Geologic Mapping Program. In particular, the Federal component of the program has undergone major changes in the past 2 years, including a new focus on urban geology, on relevant science that addresses pressing national issues, on team projects, and on partnerships with National, State, and local agencies. We anticipate continued focus on these areas, and we seek to enhance our ability to provide geologic map data that meet the needs of clients within both the public and private sectors.

Cooperative Geologic Mapping in the Mid-Atlantic Urban Corridor

J. Wright Horton, Jr.
Geologic Division, U.S. Geological Survey

The U.S. Geological Survey (USGS) Geology of the Mid-Atlantic Corridor (GOMAC) project, under the

National Cooperative Geologic Mapping Program, conducts geologic mapping and related investigations in the urban corridor extending from Virginia to New Jersey. This zone of rapidly growing and coalescing cities and towns has sustained three centuries of urban growth. Spatial geologic information is needed to address a host of issues and applications involving land use, water and aggregate resources, avoidance and remediation of natural and induced hazards, and fragile environments in the Chesapeake Bay watershed.

Project efforts are directed to complete 1:100,000-scale geologic mapping of the Washington-Baltimore urban area, to complete geologic maps of New Jersey in cooperation with the New Jersey Geological Survey (NJGS), to complete geologic mapping in progress in cooperation with the Virginia Division of Mineral Resources (VDMR), to investigate and interpret the regional geologic history and framework as a foundation for all applications, and to work with other agencies and customers to identify useful information products that can be derived from the geologic mapping.

Production of geologic maps in this region by GOMAC is enhanced by building on a legacy of previous work and by collaboration among scientists of the USGS and State Geological Surveys. Bedrock and surficial geologic maps covering the State of New Jersey (USGS Miscellaneous Investigations Maps I–2540–A–D) were recently compiled in cooperation with the NJGS; the first map (I–2540–A), by Drake and others (1996), has been published, and the remainder are in production. In the Washington-Baltimore urban area, 1:100,000-scale geologic maps of 30′ × 60′ quadrangles are being rapidly completed for the National Geologic Map Database. A geologic map of the Leonardtown, Md.-Va., quadrangle has been released as a USGS Open-File Report (McCartan and others, 1995). Geologic maps of the Washington West quadrangle, D.C.-Va.-Md., and Fredericksburg, Va.-Md., quadrangle (Mixon and others, in press) were recently submitted for publication, and color plots have been generated from preliminary digital coverages. In collaboration with the Maryland Geological Survey, geologic mapping of the Frederick, Md.-Va.-W.Va., and Washington East, D.C.-Md., quadrangles is well underway. Collectively, these geologic maps of the Washington-Baltimore area will provide a foundation for addressing issues where urban growth is spreading across diverse geological environments of the Atlantic Coastal Plain, Appalachian Piedmont (including Mesozoic Culpeper basin), Blue Ridge, Great Valley, and Valley and Ridge provinces. In accord with interagency agreements, collaborative 1:100,000-scale geologic maps with VDMR are being completed for the Appomattox, Va., and South Boston, Va.-N.C., 30′ × 60′ quadrangles. The GOMAC project continues to produce 1:24,000-scale geologic maps in response to the strong demand for detailed information in areas of urban and suburban growth. The quality and accuracy of 1:100,000-scale geologic maps are strongest where these compilations are undergirded by more detailed mapping and related investigations. Special-purpose maps derived from the basic geologic maps include lithogeochemical maps of the Chesapeake Bay watershed for the USGS Fragile Environments Program and maps delineating potential sources of aggregate for the USGS Mineral Resource Surveys Program. Scientific papers are important for documenting the research and assuring the credibility of interpretations on geologic maps for all applications.

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Geologic Maps—Foundation for Ecosystem Management

Emery T. Cleaves
Director and State Geologist,
Maryland Geological Survey

Geologic maps are a fundamental foundation for ecosystem management concerns. The living resources components, including the human component, have a spatial organization imposed upon them by the geologic framework. The geologic framework, defined by geologic mapping, provides a way to organize and assess resource, hazard, and environmental data relative to human activity. In Maryland, the Piedmont and Coastal Plain terrains illustrate the contrasting opportunities and constraints (fig. 1). The Piedmont terrain is underlain by crystalline rocks. It is characterized by narrow valleys with steep slopes, interfluves of restricted areal extent, and occasional broad flat-bottomed valleys underlain by marble. The Coastal Plain is underlain by unconsolidated sediments (sand, silt, clay). The terrain is characterized by broad plains of low relief and extensive wetlands along major rivers.

In the Coastal Plain, water for urban use, agriculture, and private homes comes from ground water supplied by

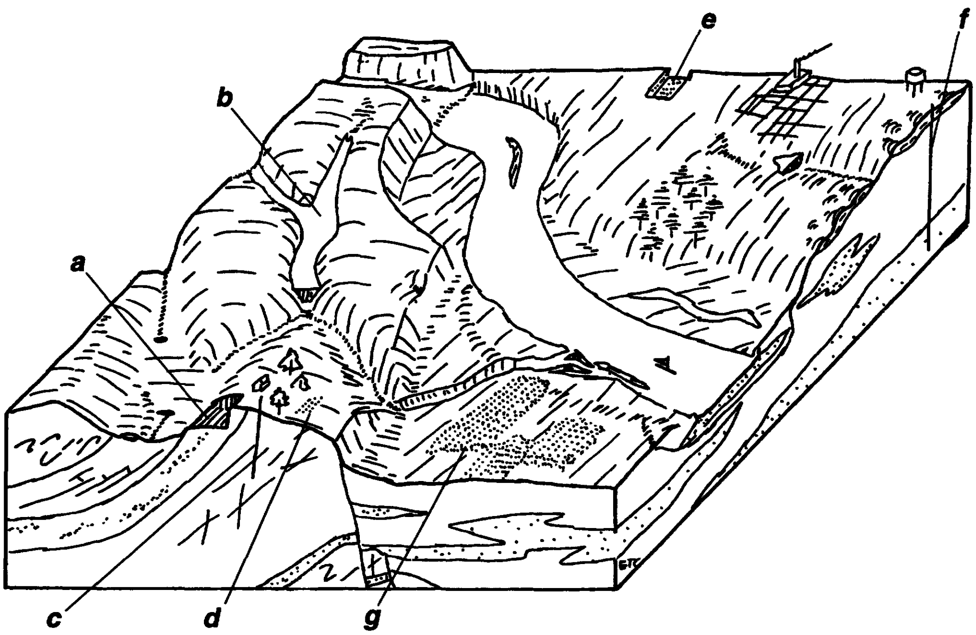

Figure 1. Abiotic framework and examples of contrasting human activities. Piedmont (left side): a, quarry in quartzite; b, water-supply reservoir; c, private well in fractured rock for a home; d, small fields for crops. Coastal Plain (right side): e, sand and gravel quarry; f, public water supply from sand aquifer; g, large fields for crops.

wells drilled into underlying sand aquifers. In the Piedmont, however, urban water needs are supplied by surface-water reservoirs. Private homes and small towns beyond urban water supply systems are supplied by wells drilled into fractured crystalline rocks. Aggregate for building and road construction comes from sand and gravel pits in the Coastal Plain and from rock quarries in the Piedmont.

In these and other ways, humans utilize the geologic components of the particular ecosystems that are available. These geologic components are organized and displayed on geologic maps.

Geologic Information—Market Position in the Metropolitan Area

Wayne L. Newell
Geologic Division, U.S. Geological Survey

Urban systems focus the flow of resources and disperse the effluents of processes that define the quality and viability of life among inhabitants. The allocation of basic resources may be fairly straight forward in "frontier" urban areas that unfold across previously undeveloped spaces. Much of the land in the Western States, for example, is public, and the development of geologic map information is a largely uncontested public asset. By contrast, in the oldest urban areas of the Eastern United States, land is generally recycled from previous use or uses. Not only has the landscape been used before, but the decisionmaking process functions within an antecedent structure of local to national government agencies and private enterprises; decisions regarding the disposition of largely private lands are complicated. Publicly produced geologic information becomes iterative and difficult to apply uniformly across the many jurisdictions. A new vision is needed for the assembly and application of spatial, geotechnical information as a "public good." Resources gathered across a region and effluent dispersed at great distances from the source should be evaluated with uniform, quality information at a compatible scale; much of the needed data and the tools for analysis are available. The "frontier" of eastern urban development is not empty land. The "frontier" is the process of developing consensus for the sustained use of natural systems.

PANEL DISCUSSIONS—
ABSTRACTS OF COMMENTS

PANEL 1. URBANIZATION AND WATER QUALITY

Moderator: *Emery T. Cleaves, Director, Maryland Geological Survey, Baltimore, Maryland*
Michael E. Bialousz, Planning Associate, Lord Fairfax Planning District Commission, Front Royal, Virginia
Ann M. Samford, P.G, P.E., President, Virginia Geotechnical Services, Richmond, Virginia
Keith Van Ness, Senior Aquatic Ecologist, Watershed Management Division, Montgomery County Department of Environmental Protection, Montgomery County, Rockville, Maryland

Opening Statement

Water is a keystone resource. We require adequate amounts of good quality water for our Washington-Baltimore urban area communities to survive and to thrive. What roles do geologic maps and related information play in assessing the quality and availability of water to meet the current and future needs of the area's human population and living resources (aquatic and terrestrial)?

Applications of Geologic Map Information Related to Urbanization and Water Quality in the Northern Shenandoah Valley

Michael E. Bialousz

The northern Shenandoah Valley can be used as a model for the entire Great Valley of the Appalachians in terms of its geology, land-use patterns, and their relationship. The valley is largely underlain by a carbonate lithology, while sandstone and shale underlie adjacent ridges. Urban and agricultural types of land use have traditionally occurred in the valley, carbonate area where the terrain is flat. This trend continues into the 21st century, fostering a need for increased geologic mapping.

Urban (residential, commercial, industrial) development today is taking place outward from the traditional city and town centers into the countryside. Due to the cost of infrastructure, these areas do not always have access to city or town water supplies, leading to the development of more wells. More wells increase the strain on ground water and result in a lowering of the water table. In a carbonate area, this increases the speed of karst processes and leads to sinkhole development and a further likelihood of ground-water contamination. As more ground water is used, the speed of its movement underground is increased, which leads to a faster solution of the carbonate rock. As this occurs, sinkhole collapse or subsidence is more likely, and the movement of pollutants becomes more rapid and may occur in more directions. Eventually, the ground water comes to the surface as springs, which then contaminate streams, the other major source of water in the area. Therefore, geologic mapping is needed to prevent these types of problems before they happen. Accurate mapping of existing and potential karst features is essential in order to restrict development in sensitive areas, lessening the chance of ground-water contamination and sinkhole development. It has been noted in previous studies that many karst areas have no surface expression, making these areas especially vital to be mapped as accurately as possible.

In areas where city and town water supplies are present or in agricultural areas, geologic mapping is still essential. More urban-type development increases the chances of water contamination through stormwater runoff, underground storage tanks, and industrial pollutants. Agricultural runoff containing fertilizers, pesticides, and nutrients from animal waste also contaminates water. In areas where karst processes are active, this leads to ground-water and surface-water contamination to the immediate and surrounding areas. In carbonate areas, it is not always clear exactly what direction the ground water is traveling, further complicating the problem.

As counties and localities develop geographic information system (GIS) capabilities, it would be extremely helpful if the geologic mapping data could be made available in a digital format. In addition, the most accurate mapping methods should be used, including global positioning systems (GPS's), if possible. With this accomplished, counties and localities will be more prepared to plan their future in a sustainable fashion.

Geoenvironmental Applications of Geologic Map Information

Ann M. Samford

Virginia Geotechnical Services is an engineering consulting firm offering specialized services in geotechnical engineering and offers soil and ground-water contamination, development, and permitting services. Geologic maps provide the fundamental data we use to understand site conditions. We use geologic maps to develop our first conceptual model of subsurface conditions of the site, and our subsequent investigations are based on this model.

We rely most heavily on geologic mapping for the following general types of projects:

Water resource evaluations
Water quality issues at landfill and hazmat sites
Landfill permitting studies
Wetland delineation studies
Foundation design studies
Geologic hazard projects
Planning and siting studies

We need complete 7.5-minute geologic mapping coverage of developing areas, as follows:

Geologic data support cost-effective land planning and development. With a limited budget, we should focus on areas with significant development plans, areas that are developing in spite of significant geologic constraints, and areas that current demographic data indicate will develop in the next 5 to 10 years. Existing 7.5-minute geologic mapping should be updated periodically.

Expanded data that could make future geologic maps more useful include the following:

Background water quality information (ppb)
Continued (increased?) focus on geologic hazards
Updated data delivery methods (soft copies, GIS, Internet)
Move to standardized terminology (ASTM)
Geotechnical description of geologic formations (not conjecture about bearing capacity)
Geotechnical implications of geologic history
Updates of existing geologic maps

Future geologic mapping efforts should be part of a long-range plan for supporting development.

Applications of Geologic Map Information for Assessing Water Quality and Maintaining and Restoring Living Resources

Keith Van Ness

The Montgomery County, Md., Department of Environmental Protection (DEP) has developed a comprehensive **Long Term Stream Monitoring Program** as part of its National Pollutant Discharge Elimination System (NPDES) municipal stormwater-management permit. The goals of the Long Term Stream Monitoring Program are—

- To assess the full range of biological, chemical, and physical stream conditions and
- To protect, maintain, and restore high quality conditions in Montgomery County waters.

An understanding of underlying geology and geologic processes is fundamental to this program. Geologic information is the foundation from which to understand the natural variability observed in the streams in the Piedmont ecoregion. Montgomery County is almost entirely within this ecoregion. Underlying geology and geologic processes influence stream base-flow recharge, ground-water flows, stormwater runoff, stream morphology, and composition of streambed materials. The Culpeper basin streams tend to have "droughty" base flow and "flashy" stormwater runoff. Channel morphology is shaped by these flow types. Areas of Montgomery County with underlying phyllite geology have stable base-flow patterns with "flashy" stormwater runoff. Channel morphology tends to have a wide storm runoff channel and a smaller base-flow channel. Bed materials here are larger cobbles and small boulders. Streams in the eastern part of the county with underlying schist geology have base flows that are not as stable as streams in the phyllite areas. Streams in schist areas with low imperviousness levels do not appear to have a "flashy" response to storm events, perhaps as a result of the deep loamy soils present in this area.

The application of geologic information is basic for many DEP programs. For example, stream reference conditions have been established for the three subecoregions within Montgomery County to account for the natural variability due in part to the three main geologic areas described above. These reference conditions serve as a "yardstick" to assess the water quality of all other Montgomery County streams. An understanding of underlying geology and geologic processes is also used in the recently developed **Countywide Stream Protection Strategy** to develop countywide resource conditions. The strategy also describes each watershed's unique stream hydrology, morphology, and other characteristics—characteristics that are better understood with the application of geologic data. Finally, recently enacted Montgomery County legislation has created **Special Protection Areas** that utilize geologic data, as well as data on regional landscape, hydrology, and stream morphology to develop and implement numeric and narrative performance goals that provide an extra level of protection to maintain existing high or sensitive water quality in watersheds planned for medium to high development.

Our current need for specific geologic map information is for the data to be at a large enough scale to be directly applicable to the scale of coverage used in Montgomery County mapping applications. We also need geologic features or processes that directly influence stream hydrology and morphology to be clearly and accurately mapped on large-scale geologic maps. These geologic processes or features could be provided through a map overlay. We also need to have geologic processes data available in digital format for application in a GIS environment. Many times, our need for geologic information is immediate and often in response to time-sensitive issues. Digital GIS data make it possible to compile mapped information in a quick and accurate fashion.

PANEL 2. CREATING DURABLE HABITATS

***Moderator:** Emery T. Cleaves, Director, Maryland Geological Survey, Baltimore, Maryland*
Michael L. Bowman, Principal Scientist, Tetra Tech, Inc., Owings Mills, Maryland
Lindsay McClelland, National Park Service, Geologic Resources Division, Washington, D.C.
Michael E. Slattery, Associate Director, Wildlife and Heritage Division, Maryland Department of Natural Resources, Annapolis, Maryland

Opening Statement

The living resources (aquatic, terrestrial and human) have a spatial organization imposed upon them by the geologic components and processes of the ecosystem. How does the information from geologic maps contribute to our understanding of the habitats of the Washington-Baltimore ecosystem complexes?

Accurate Resource Assessments, the Key to Creating Durable Habitats

Michael L. Bowman

Prior to creating durable habitats, existing terrestrial and aquatic habitats must be accurately assessed to determine their existing condition. In many instances, mapped geological information is one of the important components supporting natural resources assessment. This type of information has played a key role in several projects in Maryland and Virginia in which I've been involved. Geological information can be applied across a wide spatial scale of assessment and habitat creation activities. Examples of regional-scale assessments that relied on mapped geological information include—

- The delineation of ecoregions and subecoregions,
- The Maryland Synoptic Stream Chemistry Survey, and
- The Maryland Critical Loads Study.

At the local or site-specific scale, the following projects have relied in part on mapped geological data:

- Stream restoration,
- Habitat assessment, and
- The Western Maryland Watershed Liming Project.

Each of these efforts either provided an assessment of existing conditions or incorporated an assessment as one of its elements. The ultimate focus of all of these projects was to determine or restore habitat quality for native biota.

Geologic Mapping in Support of Ecosystem Assessment and Management

Lindsay McClelland

In a fundamental sense, geology is the foundation upon which terrestrial ecosystems are built. In recognition of the importance of geology to ecosystems, the National Park Service (NPS) Inventory and Monitoring Program, established to support NPS ecosystem management, includes geologic map data as a basic component of the multilayered geographic information systems being developed for the parks. Park natural-resource managers will be able to combine digital surficial and bedrock geologic-map data with topography, vegetation maps, soils maps, and wildlife inventories. The NPS is in the process of identifying, acquiring, and digitizing all available geologic maps of national parks through agreements with the Association of American State Geologists and the USGS.

In the Mid-Atlantic region, two geologic mapping projects in national parks should particularly be highlighted. Along the C&O Canal from Washington, D.C., to Cumberland, Md., Scott Southworth is generating a 180-mile-long strip map that illustrates the region's primary geologic provinces from the Coastal Plain into the Appalachians. This map will provide a fundamental tool for comparing geological changes with biological variation through the length of the park. In Shenandoah National Park, Ben Morgan and his colleagues are mapping dramatic debris flow deposits that have had major effects on stream ecosystems in the park. Continuing work will focus on surficial geology with direct links to a number of park ecological issues.

Geologic mapping data from Art Schultz and Scott Southworth in Great Smoky Mountains National Park is being eagerly sought by park ecologists. The terrain in the park is steep, and vegetation is junglelike, making ground access challenging. By combining topography and slope direction with bedrock and surficial geology, ecologists will target areas that have a high potential for harboring threatened and endangered species.

Lucy McCartan and colleagues are developing mapping techniques to characterize the geochemistry of bedrock over broad regions. As this approach is refined, and if it includes targeted analyses of the complex data for land managers, it could be a powerful technique in better understanding the geochemical basis for ecosystems and the potential for external threats to those ecosystems.

Several geologic environments from the Mid-Atlantic region are known for supporting distinct ecosystems that often include rare and (or) endemic plants and animals. Geologic mapping enables land managers to target these unusual environments for special attention. Where ecologists have identified unusual assemblages, geologic mapping will help them understand why they have developed at a particular site and will provide key data for their effective management.

- Limestone and the associated karst environments are characterized by distinctive hydrologic regimes and cave systems. Cave ecosystems are particularly fragile because of their vulnerability to pollution and often include endemic and rare species, particularly bats and invertebrates. From the land manager's perspective, detailed geologic mapping in karst areas is most effective if it provides locations of cave openings, losing streams, springs, and fracture systems to help determine the controls on subsurface water flow. Note that, to protect caves and their ecosystems from damage and vandalism, Federal law prohibits revealing locations of cave openings to the public. Cave locations should be provided to land managers but not published in electronic or paper map products. USGS projects near two national parks—Buffalo National River, Arkansas (led by Mark Hudson), and Ozark Scenic Riverways, Missouri (led by Rich Harrison)—are addressing key land-management issues by assessing subsurface flows of pollutants.
- The soils that develop over limestone are often thin and differ substantially from the region's typical acid clays. Limestone cliff faces provide dry, chemically distinct environments similar to those found in semiarid to arid parts of the West. These support very different plant communities, including endemics such as tall blazingstar (*Liatris aspersa*) (Terwilliger, 1991).
- Serpentinite-dominated systems, rich in magnesium and iron but impoverished in many chemical components that most plants need to prosper, create unusual ecological communities.
- Shale barrens develop on steeply sloping sites, where the shale flakes at the surface reduce water infiltration, and mass-wasting limits tree growth to scrub pine-oak (*Pinus virginiana/Quercus prinus*). Especially if south-facing, these environments tend to be hot and dry, with a characteristic assemblage of endemic plants, including Virginia endangered species Millboro leatherflower (*Clematis viticaulis*), shale barren rockcress (*Arabis serotina*), and Kate's Mountain Clover (*Trifolium virginicum*) (Terwilliger, 1991).

Our challenge is to link the different disciplines necessary to put geologic maps to work addressing ecological issues. The incorporation of the Biological Resources Division (formerly the National Biological Service) into the USGS provides an excellent opportunity to build key parts of that linkage.

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Some Views on the Role of Geologic Information in Conserving Maryland's Natural Diversity

Michael E. Slattery

Recent reorganization of the Maryland Department of Natural Resources (DNR) resulted in the genesis of **Heritage and Biodiversity Conservation Programs** (HBCP), an interdependent set of programs with a unified mission—to provide for the long term conservation of the full array of native ecosystems, natural communities, and species that constitute the biological integrity of Maryland, for the benefit of this and future generations. Maryland's biological heritage and natural diversity are diminishing, along with the integrity of ecological functions that are the underpinnings of our natural world. Along with this loss of diversity, elements of the very fabric of natural history and culture that Marylanders so cherish, indeed that support human life and spiritual well-being, are significantly impoverished.

DNR has had many biodiversity-related successes in its past. However, those successes have been hard fought, somewhat sporadic, and often opportunity driven. HBCP's aim is pursue the conservation of biodiversity in a systematic, strategic way. To accomplish this, we need to answer four questions. (1) What living things and ecosystems should we conserve and protect? (2) Where should we protect those resources in order to get the greatest return on our investment of time and energy? (3) How should we manage those resources once conservation and protection measures have been put in place? (4) Are we succeeding in the achievement of our mission? The answers to these questions must be rooted in good science. The scientific information considered must be understandable to a wide variety of public and private decisionmakers. The application of that information must result in meaningful conservation measures on the ground.

In order to most efficiently answer the first and second questions, HBCP has shifted its emphasis to concentrate on ecological **community-oriented** approaches, as opposed to more traditional species-oriented approaches. Specifically, we have chosen to focus on **plant community alliances** to guide our conservation efforts. This is not to say that we will disregard the importance of rare species conservation. We will look to rare species data to differentiate between otherwise similar examples of community types and further refine our conservation priorities geographically.

A **community type** is an assemblage of species that recurs under similar habitat conditions and disturbance regimes, which are classified in a standard system. A plant community alliance is the smallest scale level at which recurring assemblages of plants are discernible on the landscape. Plant community alliances have unique ecological functions, some identifiable and some presumed, which are unique to that community alliance and which have inherent conservation value. Protecting and conserving communities are efficient strategies for conserving the full range of ecological functions existing in a given landscape, which support the diverse and interconnected community of living things (biological diversity). This is especially necessary for the protection of more common species and those we know very little about. It is commonly referred to as the "coarse filter" approach to conservation.

Identifying and classifying plant community alliances require extremely sophisticated botanical assessment, as well as some understanding of the physical environment with which living organisms interact. The functional relationships between biotic and abiotic ecosystem components must be considered. The nuances of variation between plant community alliances are a result of sometimes subtle, and sometimes not so subtle, differences in surface and shallow subsurface geology and hydrology, among other abiotic variables.

So, community ecologists and other conservation ecologists rely heavily on geologic maps and other information to perform their life's work. Geology is an important consideration for planning fieldwork and is used extensively by field ecologists in their work to traverse remote areas with few landmarks. It helps us to key in on unique features when we hunt for certain rare species with very specific habitat requirements. For example, the State endangered green salamander is known to occur only in Pottsville Formation sandstone outcrops in Garrett County's wilder forests, and several rare small mammal species occur with regularity in western Maryland forests with limestone talus substrates. Geologic features also define some of our most unique and biologically diverse natural community types, such as our limestone caves, sandstone glades, shale barrens, and xeric dunes. The limits of Maryland's relic short and tall grass prairies and oak savannahs at Soldier's Delight, which are now the focus of a major restoration initiative, are determined largely by the extent of serpentine soils.

Geologic maps and information are critical in many ways to the conservation of biological diversity in Maryland. Of primary importance at the moment are the implications this information may have for future iterations and refinement of the classification of plant community alliances. The classification is necessary to develop baseline inventories of natural communities and important habitats to be used in setting conservation priorities. A conservation planning process will make extensive use of such information to identify a core network of lands representative of Maryland's diverse natural communities and native species. The process will geographically assemble and arrange ecologically targeted areas that, presumably, act collectively in the landscape to provide a full range of ecological niches supportive of our diverse and interconnected communities of living things. We can then work systematically to promote and facilitate the conservation and protection of those areas. From this perspective, geologic information plays a critical role in this vision of creating a durable and self-sustaining habitat that supports the full complement of Maryland's natural diversity.

PANEL 3. GEOLOGIC INFORMATION FOR THE URBAN SYSTEM

Moderator: *J. Wright Horton, Jr., Geologist, U.S. Geological Survey, Reston, Virginia*
Alex C. Blackburn, Interpretive Soil Scientist, Virginia Cooperative Extension, Loudoun County Extension Office, Leesburg, Virginia
Thomas E. Carroll, Manager of Government Relations and Business Development, Vulcan Materials Company, Mideast Division, Winston-Salem, North Carolina
A. David Martin, Division Chief, Engineering Geology Division, Maryland State Highway Administration, Brooklandville, Maryland

Opening Statement

The Washington-Baltimore urban system requires natural aggregate, soil, water, and energy resources to sustain economic vitality and quality of life. Human activities such as construction require an understanding of the performance and behavior of earth materials and information about potential hazards. How is geologic map information useful for addressing engineering problems and for sustaining adequate resources to meet future demands without unacceptable environmental degradation?

The Use of Geologic Information in Loudoun County, Virginia

Alex C. Blackburn and Lawrence Stipek

Loudoun County, located just west of Washington, D.C., began growing very rapidly in the mid-1980's. The county began improving its processes and its information base at that time so as to better manage the many problems associated with new development. A geology coverage was created in cooperation with the U.S. Geological Survey over a 5-year period. The new information, completed in 1992, was a refinement of earlier geologic mapping in the Triassic basin and included new, more detailed mapping in the Blue Ridge (western) portion of the county.

The initial purpose of the new geologic mapping was to serve as the foundation for a complete revision of the county's soil maps. The new, very large scale (1:2,400) soil maps were compiled from earlier maps, new field surveys, and the new geologic data. The new geologic information was also the framework for analysis and modeling of the county's ground-water data base. Developed and maintained from well logs, the data base was used to analyze the availability of ground water in the rapidly developing rural areas. The geology mapping was then used extensively in a landfill site selection study conducted for and by the county. This work culminated in the selection of a site, with net savings estimated to be $1,500,000 (U.S. Geological Survey Circular 1111, p. 36).

Today the county continues to use the refined geologic data. The data were incorporated into the county's geographic information system (GIS), and a new map produced that displayed both geology and the county's street centerline as a reference. The county has a policy of providing open access to its GIS and has distributed the geologic data to others for engineering purposes. The designers of the Dulles Greenway, a privately funded and constructed toll-road, used the county's flood-plain, parcel, and other data, together with geology, in the initial design phase of the project.

Perhaps more importantly, the public has direct access to the GIS at two public access terminals. The most common use of geologic information today is to make very important, personal decisions, such as purchasing property, analyzing the cost of making improvements such as a new fence or a foundation for a house, or estimating the yield of a new well. The latter is an important, almost daily activity at the Office of Mapping and Geographic Information public information counter and at the Virginia Tech Extension Office. Staff routinely help the public to search the geographic data base, display and access the well data, and compare it to the geologic map. Geology is an important component of the county's information base.

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Geologic Maps and Mineral Resources for the Urban System

Thomas E. Carroll

Virginia's Mineral Mining Industry—Overview

- Approximately 84 million tons of nonfuel minerals were produced in Virginia in 1996, with a value in excess of one-half billion dollars. The majority, roughly 92 percent, was from the production of aggregates (crushed stone and sand and gravel) from 133 quarries and 270 sand and gravel mines.
- Virginia consistently ranks in the top 10 in the Nation in crushed stone production.
- Roughly 12 tons of aggregate are required annually for each Virginia citizen.

Exploration

- Unlike a shopping center, housing development, school, and so on, mining companies do not have the luxury of being able to locate mines and quarries where we want them to be. Minerals are where you find them—or where the Geological Surveys map them.
- Simplistic?—The reality is that geological maps are the base maps that generate interest and investment from the mineral industry. We use these maps as the fundamental building block in our exploration programs—whether to identify previously unknown geologic terrains and (or) geochemistry for precious metal deposits or something as simple as depth of weathering—what we in the aggregate business refer to as overburden.

Consumption/Growth

- Recall the aggregate consumption figure I gave you earlier? Virginia's population is projected to grow from 1994 to 2020 by roughly 30 percent or 1.9 million people.
- That means additional annual aggregate demand of roughly 23–25 million more tons of aggregate.
- A large percentage of this growth will come in Northern Virginia as part of the State's "golden crescent."

Role of Planning

- Local governments must plan ahead to ensure a continuous supply of locally available aggregates. If you truck this material over 20–30 miles, the cost of transportation can exceed the cost of the materials. This can and does significantly impact local government and private construction costs and the overall cost of living in an area when you consider that 95 percent of asphalt and approximately 85 percent of concrete consists of aggregates.
- Urban sprawl without any thought to future mineral development must cease.
- Approximately 1 year ago, Virginia took the first step in encouraging local governments to include the need for mineral resources as one of the elements to evaluate when developing and amending their comprehensive plans.
- This legislation will place an increased burden on the Geological Surveys to supply local government with this basic information. Unfortunately, it will take decades to complete the geologic mapping (over 100 years) and mineral resources mapping (over 17 years) at current staffing levels. Remember the issue identified by users of this information—it must be timely.

Conclusion

- In supplying geological information, the challenge to the Surveys is not only how quickly can the data be produced and published but also how must the data be repackaged to be less technical and more interpretive for the nongeologist (elected officials, land-use planners, and so on) to readily use. Through greater use, the public will understand the fundamental importance that geology plays in our everyday lives.
- Emphasis should be placed on publishing data electronically (GIS and so on) and on county and planning district boundary basis rather than on topographic quadrangle sheets.

Geologic Information As Related to Maryland Highway Construction and Maintenance

A. David Martin

Geologic Mapping

This information is a basic unit of input for many Maryland State Highway Administration (SHA) activities in Project Planning, Design, and Maintenance. While our current concerns require that we focus on karst areas, we use geologic mapping for all our projects statewide. Rock cuts, coal mines, aggregate sources, blast design, surface- and ground-water contamination, landslide studies, and stormwater management are all examples of problems that we have to deal with where good geologic mapping is a basic tool. If mapping were not available, we would have to do it ourselves. The result would be a lesser product at more cost and time.

The economic benefit of accurate mapping is that we can clearly define the limits of our work, thus optimizing the scope of costly geotechnical exploration and design. On the other hand, modern mapping helps us conduct enough studies so that we do not miss geologic hazards. The cost to the State of even one sinkhole in the roadway or one small landslide is measured in millions of dollars. The cost to the State of an unexpected sinkhole on a construction site can easily run to hundreds of thousands. Mapping does not locate specific hazards, but it does guide the engineering geologist and geotechnical engineer in developing an adequate subsurface investigation.

Currently SHA is building a data base of geologic hazards on the highway system. This data base will include records of sinkholes, landslides, rockfall, and coal mines. The goal is to make the data base compatible with the geographic information system (GIS) being developed by a consultant. The value of current geologic mapping available through GIS will enhance our ability to understand and interpret the field observations that we make for ourselves.

PANEL 4. NATURAL AND INDUCED HAZARDS—AVOIDANCE AND REMEDIATION

Moderator: J. Wright Horton, Jr., Geologist, U.S. Geological Survey, Reston, Virginia
Paul T. Jacobson, Environmental Consultant, Langhei Ecology, Glenelg, Maryland
Douglas J. Riddle, P.G., Vice President of Business Operations, Applied Recycling, Inc., Frederick, Maryland
Sean Smith, Environmental Specialist, Watershed Restoration Division, Maryland Department of Natural Resources, Annapolis, Maryland

Opening Statement

Natural hazards such as slopes in unstable material, karst subsidence, expandable clays, faults, flooding and erosion, and radon are of increasing concern to personal safety and property value as development spreads across the landscape. Other hazards induced by human construction, pollution, and waste disposal increase with urban growth and test the sensitivity of natural environments. How is the information from geologic maps useful in attempting to avoid, or to seek remediation of, environmental hazards?

Comprehensive Environmental Management—Ecoregion and Watershed Approaches Using Geologic Information

Paul T. Jacobson

In recent years, flooding in several hydrologically altered river basins across the country has resulted in loss of life and extensive property damage. Likewise, landslides on logged slopes in the Pacific Northwest have resulted in damage to property and risk of injury and death in adjacent residential areas. These and other disasters have highlighted connections between environmental management and ostensibly natural hazards. The emerging paradigm for comprehensive environmental management is the ecosystem approach, which has been endorsed by the U.S. Environmental Protection Agency (USEPA) and many State agencies and is being applied at a variety of spatial scales across the United States.

A fundamental requirement of the ecosystem approach to environmental management is definition of system boundaries by using ecological criteria. Two approaches have been widely used for defining ecosystem boundaries for environmental management. One approach is the **ecoregion approach**, in which areas are delineated on the basis of similarity of geology, climate, soils, biota, and hydrology. Ecoregions are considered useful units for management because they are relatively homogeneous with respect to their structural components and dominant ecological processes. The other common approach is the **watershed approach**, in which ecosystems are delineated by using hydrologic boundaries. Both approaches rely upon mapped geologic information.

The ecoregion approach is strongly influenced by geology, as is apparent from examination of continental-scale ecoregion maps prepared by USEPA (Omernik, 1987). Current work by USEPA focuses on developing more precise, homogeneous ecoregions mapped at a larger scale; this requires accurate, high-resolution geologic maps.

The watershed approach defines ecosystems on the basis of the flow of water. The approach was inspired by the classic, long-term Hubbard Brook Ecosystem Study (Likens and Bormann, 1977; Bormann and Likens, 1994), which used the powerful mass-balance approach with paired treatment and reference watersheds. The geologic setting of the Hubbard Brook Ecosystem Study, however, was well known and nearly ideal. High topographic relief combined with shallow, impervious bedrock ensured precise definition of the system boundaries. Widespread use of the watershed approach implies more complex geologic settings and a need for extensive coverage of large-scale geologic and hydrogeologic maps.

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Examples of Geologic Map Applications in the Washington-Baltimore Region

Douglas J. Riddle

Applications of geologic map information use by the speaker are presented in the context of 20 years of work in the Baltimore-Washington area. The focus of the talk is to highlight a series of examples of projects where the speaker has been the principal investigator and geologic maps have been used. These projects fall under the broad categories of economic geology, engineering geology, and environmental geology. The primary project examples deal with the panel discussion topic of natural and induced hazards, but other examples are also presented. The three categories and the respective project applications discussed are as follows:

Economic Geology

- Sand and gravel deposits and land value (Prince Georges County, Maryland)
- Regional clay sources identification (Delaware, Maryland, and Virginia)

Engineering Geology

- Underground energy storage and host rock selection (Maryland)
- Forensic study of trench collapse (Fairfax County, Virginia)*
- Construction claim—dewatering (Prince Georges County, Maryland)*
- General use of geologic maps for tunnels, dams, and building foundations
- Slope instability—Cretaceous clay and Marlboro Clay (Maryland and Virginia)*
- Karst and building foundations (Frederick County, Maryland)*

Environmental Geology

- Sludge entrenchment sites and leachate generation (Maryland)*
- Remediation of military installations (Virginia and Maryland)*
- Hawkins Point hazardous waste facility (Baltimore, Maryland)*
- Former chrome-ore processing facility (Baltimore, Maryland)*

The speaker's viewpoint, based on performing numerous projects in the area, is that vast amounts of data have been collected since many of the maps we are using were developed. These data deserve to be incorporated in updated maps if we are to meet the challenges of redevelopment of urban areas, brownfields development (for example, the SMART program in Maryland), and new development.

*Denotes a project dealing with a natural or induced hazard.

The Use of Geologic Maps for Protecting and Restoring Waterways and Wetlands

Sean Smith

The Maryland Watershed Restoration Division (WRD) is involved in a wide variety of activities that focus on the restoration or enhancement of wetland and stream ecosystems. Our work involves the analysis of water chemistry and physical landscape conditions that influence the quality and abundance of aquatic habitat for macroinvertebrates and finfish. It has been our experience that geologic map information has direct application in our monitoring, assessment, and restoration activities. This information is useful because of the relationship between the State's geology and the physical and chemical characteristics of the associated waterways and wetlands.

One of WRD's primary activities is related to the evaluation of best management practices for the control of nonpoint source pollution generated from land uses in both urban and rural watershed areas. General knowledge of the geological characteristics of contributing watersheds provides useful information for identifying background water-quality trends. An excellent example of this use is provided in the "Synthesis of Nutrient and Sediment Data for Watersheds within the Chesapeake Bay Drainage Basin" (Langland and others, 1995) published by the U.S. Geological Survey in cooperation with the U.S. Environmental Protection Agency. This effort evaluated the potential correlations between nutrients and sediment with respect to land uses, rock type, and physiographic province. Similar investigations can be conducted at higher resolution with more detailed geologic information. The cultivation of a greater understanding of the influence of the State's geology on surface-water quality can be helpful in the development of local and regional watershed management strategies, including the Chesapeake Bay Tributary Strategies.

The physical restoration of aquatic environments has become a significant focus of the environmental management agencies in the Washington-Baltimore metropolitan area. Stream restoration has become increasingly popular as an option for the remediation of ecological damages resulting from past land-use changes and the manipulation of natural channels for development purposes. Numerous new approaches to stabilizing natural channels or enhancing aquatic habitat conditions have been developed in recent years that give closer attention to the geomorphology of natural channels. However, in many cases inadequate attention is being given to the landscape surrounding the channel and the general geologic conditions in Maryland's primary physiographic regions. The WRD is attempting to develop improved approaches for restoration planners and designers that give more thorough consideration to the elements that influence the appearance of stream channels. An improved understanding of Maryland's geology and the landscape con-ditions occurring across the State's varied physiographic regions is the foundation for this approach. In addition, knowledge of the geologic characteristics in specific stream reaches can be used to develop conclusions regarding stream bottom sediment characteristics, stream bank stability, and the potential for widening or deepening of the channel.

The benefits of geologic mapping resources are most closely related to WRD's goal of improving the understanding of waterways and wetlands in Maryland. As with other mapping resources, they are most useful during the planning stages of watershed protection and restoration projects. They also have potential application in the design of site remediation projects. We have found them useful in the development of conclusions regarding water-quality data and believe that they have potential application in the development of criteria for the targeting of riparian reforestation and stream restoration activities. Improvements in the quality and availability of geologic mapping resources in the State will be important contributions to the State's future watershed planning activities.

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RESULTS OF STATEWIDE USER SURVEYS

A CUSTOMER SURVEY OF GEOLOGIC MAPS OF THE MARYLAND GEOLOGICAL SURVEY

James P. Reger, Maryland Geological Survey

Abstract

Geologic mapping has long been a core activity of the Maryland Geological Survey (MGS). In late 1996, the MGS conducted its first in-depth survey to identify users and uses of geologic maps. The results of this survey show that there is a broad and diverse base of geologic map users and uses and that geologic maps are generally very important to the work of the customers. Many expressed the need for more, not fewer, geologic maps.

A two-page, nine-item, multiple-choice questionnaire was prepared and distributed to more than 550 people. Response by 322 individuals far exceeded expectations. The 58-percent response rate has been described by a professional public opinion research company as "phenomenal and extraordinary, clearly indicating that respondents felt they had a stake in the results of the survey" (Mason-Dixon Market Research, Columbia, Md., oral communication, 1997).

Respondents fell into three main groups—government (39 percent), consultants (36 percent), and education (15 percent). By area of training and expertise, a slight majority cite geology (51 percent); other areas were environmental sciences (28 percent), hydrogeology (23 percent), engineering (20 percent), other sciences (15 percent), and non-science (5 percent).

Sixty-eight percent of respondents use geologic maps several times a month or more often, and 83 percent characterize geologic maps as crucial to very important in their work. Among those who use geologic maps less frequently, most consider geologic maps to be very important when they do use them.

The type of use generally reflects the work area or expertise of the user. Two uses led all others—support of environmental assessment or impact statements (60 percent) and development of site-specific evaluations (54 percent). Other main uses were academic studies (37 percent), engineering and design activities (35 percent), remediation/feasibility studies (34 percent), and land-use planning (32 percent). Nearly a quarter of respondents cited more than 20 additional uses. Underscoring the versatility or broad application of geologic maps is the fact that respondents marked an average of nearly three uses per respondent.

Three recommendations were marked on a majority of questionnaires—production of surficial geologic maps in addition to bedrock geologic maps (58 percent), production of digital maps (55 percent), and production of maps in full-color instead of "bluelines" (52 percent). (MGS began issuing geologic maps as blueline prints in 1993 as a cost-cutting measure.) Depiction of more geologic cross sections (38 percent) and depiction of engineering or physical properties of materials (36 percent) rounded out the respondents' recommendations. These results seem to cut across all customer groups.

Geologic maps are not too technical for most users. Only 17 percent recommended showing general rock types instead of traditional geologic formations (though some wanted both), and 20 percent recommended writing the explanatory text in less technical language.

This questionnaire validates the conclusion that geologic maps are relevant and useful to a diverse customer base. Customers express their need for a continuation, or even an expansion, of geologic mapping in Maryland.

Methods

During November and December 1996, a two-page, multiple-choice questionnaire was distributed to more than 550 potential or probable users of geologic maps. Several mailing lists were utilized in an effort to reach a broad sampling of geologic map customers. No attention was paid to proportions of government, academic, or private sector customers. Nevertheless, it is posited that this survey adequately represents the population of geologic map customers.

As of January 20, 1997, 322 of 558 questionnaires had been returned, but three were not tabulated because the respondents were retired and no longer used geologic maps. More than one-fourth of the respondents had obtained questionnaires by "networking" of those who had received the mail-out. The first couple of questions identified and characterized the map customers—namely, the nature of respondents' business (government, consultant, education, and so on) and area of expertise (geology, hydrogeology, environmental sciences, engineering, archaeology, soils, and so on). The last few focused on uses of and need for geologic maps and on suggestions for changes or improvements.

Results

A detailed presentation of the survey's results appears in Maryland Geological Survey Open-File Report 97–03–01 (Reger, 1997). The following is a condensation of raw data.

Reference Cited

Reger, James P., 1997, A customer survey of geologic maps and other products of the Maryland Geological Survey: Maryland Geological Survey Open-File Report 97–03–01, 36 p.

• WHAT IS THE NATURE OF YOUR BUSINESS IN WHICH YOU USE OUR GEOLOGIC MAPS?

Primary Employment	Number Responding/ Group Total	Percent Responding	Percent of Total (319)
Government			
Federal[1]	32/46	70	10
State (Maryland)[2]	58/74	78	18
State (non-Maryland)[3]	17/19	89	5
County/Municipal[4]	19/33	58	6
Other (interstate)	1/1	100	<1
Subtotal	127/173	73	40
Consultants[5]			
Corporate	95/144	66	30
Independent	21/22	95	7
Subtotal	116/166	70	36
Education			
K-12 (mostly earth science)	24/50	48	8
College (mostly geology)	26/48	54	8
Subtotal	50/98	51	16
Miscellaneous Other[6]	26/32	81	8
GRAND TOTAL	319/558	57	100

[1]Mainly geologists, hydrogeologists, biologists, environmental scientists, soil scientists, and archaeologists from the U.S. Geological Survey, the U.S. Department of Agriculture, U.S. Department of Energy, U.S. Army Aberdeen Proving Grounds, the Army Corps of Engineers, the National Park Service, the U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, the National Museum of Natural History, National Aeronautics and Space Administration, Naval Research Lab, the U.S. Nuclear Regulatory Commission, Department of Defense, and Federal Emergency Management Agency.

[2]Geologists, hydrogeologists, biologists, ecologists, resource managers, GIS specialists, archaeologists, and planners from several agencies of the Department of Natural Resources, the Department of the Environment, the Maryland Historical Trust, the State Highway Administration, and the Maryland Office of Planning.

[3]Mainly geologists from Geological Surveys of surrounding States.

[4]Mainly engineers, biologists, and planners from a variety of county agencies, such as planning, zoning, environmental protection, public works.

[5]Civil and geotechnical engineering, geological, hydrogeological, environmental, archaeological consultants.

[6]Private citizens, museums, associations, advocacy groups, extractive industry, nongeologic businesses.

Area of Specialization Among Government Respondents[1]	Federal Govt ($n = 32$)	Maryland Govt ($n = 58$)	Other States ($n = 17$)	County-Municipal ($n = 19$)
Geology (all specialties)	20 (63%)	16 (28%)	16 (94%)	4 (21%)
Hydrogeology	10 (31%)	7 12%)	3 (18%)	3 (16%)
Engineering (mostly civil and environmental)	2 (6%)	5 (9%)	1 (6%)	8 (42%)
Environmental Science (mostly ecology and biology, resource management)	9 (28%)	23 (40%)	1 (6%)	5 (26%)
Other Science: Archaeology, Environmental Planning	2 (6%)	12 (21%)	0 (0%)	1 (5%)
Nonscience (land-use planning; administration, management, geography)	0 (0%)	3 (5%)	0 (0%)	5 (26%)
Totals	43 (134%)	66 (114%)	21 (124%)	2[illegible] (137%)

[1]Does not include one questionnaire received from the Interstate Commission on the Potomac River basin, which was a composite response of eight staff members, ranging from geologists to planners to administrators.

Area of Specialization Among Consultants	Number (and % of 116)
Civil/Geotechnical Engineering Consultants	43 (37%)
Environmental/Hydrogeology Consultants	73 (63%)
Geology/Engineering Geology Consultants	16 (14%)
Economic/Exploration/Mining Consultants	7 (6%)
Archaeology Consultants	10 (9%)
Other Consultants	7 (6%)
Total	156 (134%)

- **WHICH BEST DESCRIBES YOUR FIELD OF EDUCATION, TRAINING, OR EXPERTISE?**

Category	Number of Responses (% of 319)
Geology	164 (51%)
Hydrology/Hydrogeology	73 (23%)
Engineering[1]	62 (19%)
Environmental Sciences[2]	90 (28%)
Other areas of science[3]	46 (14%)
Nonscientist[4]	16 (5%)
Total	449 (141%)

[1]65% civil/geotechnical engineering; 18% no specialty specified; 15% environmental engineering; 16% geological and mining engineering; 11% other.

[2]41% no specialty specified; 29% ecology/biology/zoology/botany; 11% soil science; 26% other (policy, planning, wetlands, hazardous materials, and so on).

[3]48% archaeology/anthropology; 17% science education; 10% general science; 30% other.

[4]38% land-use or comprehensive planning; 62% other (realty, public relations, history, geography, cartography, and general administration).

- **HOW OFTEN DO YOU USE GEOLOGIC MAPS?**

Respondent Group	Very Often (weekly ±)	Often (monthly ±)	Occasional (< monthly)	Seldom (few times/yr)	No Response
Government: Federal	44%	22%	28%	6%	0%
Government: Maryland State	52%	28%	16%	5%	0%
Government: County/City	30%	30%	40%	0%	0%
Education: K-12	12%	31%	27%	23%	8%
Education: College	31%	49%	14%	6%	0%
Consultants: Civil Engineering	37%	40%	12%	12%	0%
Consultants: Environmental Engineering	37%	40%	15%	8%	0%
Consultants: Geological/Engineering Geology	55%	27%	14%	5%	0%
Archaeologists (private and government)	36%	14%	45%	5%	0%
Ecologists/Biologists (private and govt)	35%	42%	19%	4%	0%
Hydrologists (private and govt)	44%	35%	15%	4%	1%
Totals for 319 respondents	37%	31%	21%	10%	2%

- **HOW IMPORTANT ARE GEOLOGIC MAPS TO YOUR WORK?**

Respondent Group	Crucial	Very Important	Somewhat Important	Not Very Important	No Response
Government: Federal	56%	38%	3%	3%	0%
Government: Maryland State	60%	26%	12%	2%	0%
Government: County/City	25%	40%	35%	0%	0%
Education: K-12	19%	50%	23%	0%	8%
Education: College	51%	31%	17%	0%	0%
Consultants: Civil Engineering	37%	47%	16%	0%	0%
Consultants: Environmental Engineering	55%	33%	12%	0%	0%
Consultants: Geological/Engineering Geology	68%	32%	0%	0%	0%
Archaeologists (private and government)	45%	41%	14%	0%	0%
Ecologists/Biologists (private and govt)	54%	27%	19%	0%	0%
Hydrologists (private and govt)	65%	25%	8%	0%	1%
Totals for 319 respondents	49%	34%	15%	1%	2%

• HOW DO YOU USE GEOLOGIC MAPS?

[Responses (%) by various groups of respondents to the question of how geologic maps are used. Major uses (≥50%) are printed in ***bold italic*** typeface for each group. a, Support of engineering and design activities; b, Support of environmental assessment or impact statements; c, Development of site specific evaluations; d, Support of remedial studies/feasibility studies; e, Support of land-use planning; f, Academic studies (instruction, research); g, Other]

Respondent Group	a	b	c	d	e	f	g
Government: Federal	19	***59***	***53***	28	34	***59***	34
Government: Maryland State	17	***74***	***66***	24	34	26	16
Government: County/City	***55***	***60***	30	35	***55***	10	0
Education: K-12	19	35	23	19	31	***92***	19
Education: College	9	31	20	6	23	***91***	17
Consultants: Civil Engineering	***88***	***79***	***81***	***67***	49	5	2
Consultants: Environmental Engineering	***60***	***93***	***79***	***77***	33	7	10
Consultants: Geological/Engineering Geology	***73***	***73***	***86***	***59***	41	14	36
Archaeologists (private and government)	5	***59***	***50***	9	23	***50***	41
Ecologists/Biologists (private and govt)	15	***74***	***52***	22	41	33	37
Hydrologists (private and govt)	***56***	***81***	***75***	***54***	47	21	24
Totals for 319 respondents	35	***60***	***54***	34	32	37	22

For the total 319 respondents, environmental assessment and site-specific evaluations are the major uses of geologic maps. Both of these uses need large-scale maps (that is, 1:24,000 or larger). The other listed uses are in a virtual tie (32–37 percent). Underscoring the broad application of geologic maps is the fact that 319 respondents marked a total of 868 uses of geologic maps in their work—an average of 2.8 uses per respondent. This shows that geologic maps have great versatility and applicability; their value or utility is not restricted to a few types of customers or to a few uses.

• DO YOU HAVE ANY RECOMMENDATIONS FOR CHANGING OR IMPROVING OUR GEOLOGIC MAPS?

[Responses (%) by various groups of respondents to question about recommendations. Major recommendations (≥50%) are printed in ***bold italic*** typeface for each group. a. Show rock types rather than geologic formation; b. Color maps instead of blueline maps; c. Explanatory text written in more elementary language; d. Have more cross sections on maps; e. Produce surficial maps in addition to bedrock maps; f. Add a depiction of engineering or physical properties to maps; g. Have digital maps for GIS in addition to paper maps]

Respondent Group	a	b	c	d	e	f	g
Government: Federal	28	***56***	16	***50***	***62***	41	***59***
Government: Maryland State	10	***53***	19	28	***57***	22	***62***
Government: County/City	10	45	20	25	35	***50***	***80***
Education: K-12	40	***56***	***64***	36	44	20	36
Education: College	14	***57***	23	43	***57***	40	***51***
Consultants: Civil Engineering	14	***53***	23	40	***60***	***67***	***60***
Consultants: Environmental Engineering	15	***51***	18	36	***68***	49	***55***
Consultants: Geological/Engineering Geology	9	***59***	14	41	***68***	***50***	36
Archaeologists (private and government)	14	18	9	9	***50***	9	***59***
Ecologists/Biologists (private and govt)	35	***54***	42	23	***65***	23	***65***
Hydrologists (private and govt)	14	***53***	12	***50***	***74***	***53***	***61***
Totals (%) for 319 respondents	17	***52***	20	38	***58***	36	***55***

Three recommendations are in a virtual tie—production of surficial geologic maps in addition to bedrock geologic maps, production of digital maps, and production of maps in full-color instead of "bluelines." Although the Maryland Geological Survey concurs, implementation poses challenges. Furthermore, contrary to an all-too-common misperception, this survey (responses a and c) indicates that geologic maps are not generally considered by their users as too technical.

VIRGINIA DEPARTMENT OF MINES, MINERALS, AND ENERGY, DIVISION OF MINERAL RESOURCES CUSTOMER SURVEYS—1993 AND 1994

Stanley S. Johnson, State Geologist, Virginia Division of Mineral Resources

The Virginia Division of Mineral Resources, in its continuing effort to receive customer input into its activities, conducted two surveys. The first was by its Geologic Mapping Advisory Committee. The committee wanted information from local governments regarding their assessment as to the importance of geologic mapping in 12 areas—waste management, ground water, surface water, natural hazards, industrial minerals, energy, urban considerations, industrial land-use, low-level radioactive waste, corridors, wetlands, and recreation. The survey was important because the committee wanted to give recommendations to the State Geologist regarding the STATEMAP program. The survey was conducted in June 1993; questionnaires were sent to 95 counties and 21 planning districts. The response was 66.3 percent for counties and 66.6 percent for planning districts. The following are the results:

Subject Assessment	Extremely Important		Important		Not Very Important		Not Important	
	County	PDC	County	PDC	County	PDC	County	PDC
Waste management	58.7	71.4	28.5	28.5	6.3	0	4.7	0
Ground water	79.3	85.7	19.0	14.2	0	0	1.5	0
Surface water	49.2	50.0	39.6	35.7	11.1	14.2	0	0
Natural hazards	25.4	21.4	41.3	50.0	31.7	21.4	1.6	0
Industrial minerals	23.8	28.6	33.3	42.8	33.3	28.5	9.5	0
Energy	12.7	28.6	30.2	35.7	44.4	21.4	9.5	14.3
Urban considerations	15.8	35.7	38.1	21.4	30.1	35.7	11.1	7.1
Industrial land use	38.1	42.8	46.0	42.8	11.1	7.1	1.6	0
Low-level radioactive waste	15.8	35.7	30.2	21.4	30.1	35.7	0.6	7.1
Corridors (roads and so on)	34.9	50.0	47.6	28.5	12.7	21.4	3.1	0
Wetlands	28.5	28.5	50.7	50.0	14.2	21.4	4.7	0
Recreation	14.2	21.4	42.8	35.7	38.1	35.7	4.7	7.1

*All numbers are in percent; PDC = Planning District Commission.

The second customer survey was conducted in November/December 1994. This survey was more generalized and directed to all customer groups. The survey was mailed to names on the "Virginia Minerals" mailing list, was distributed to customers purchasing items in the sales office, and was included in each sales order that was mailed out. The survey was conducted for 30 days. A total of 706 questionnaires were distributed; the return was 222 or 31.4 percent. The following are the results of this survey:

General Public	71	31.9%
Consulting company	25	11.2%
Consultant	17	07.6%
Industry	32	14.4%
Government	41	18.4%
Education	36	16.2%
	222	99.7% of those returned

Geologic and Mineral Resources

What kinds of geologic and mineral-resources information do you usually request and (or) purchase?

	Geologic Maps	Coal Data	Oil/Gas Data	Mineral Data	Aggregate Data	Hydrogeologic Data
Total	197	24	20	114	33	51
Industry	29	5	7	22	8	6
Education	31	2	1	13	2	1
Consultant	17	3	0	10	8	10
Consulting company	25		6	8	3	17
General public	58		3	46	3	3
Government	37		3	15	9	14

Do you request information (on an average):

	Weekly	Monthly	Yearly	As Needed
Total	1	40	28	164
Industry	0	3	4	28
Education	0	4	8	23
Consultant	1	6	0	13
Consulting company	0	13	2	18
General public	0	6	9	57
Government	0	8	5	25

Is the information provided in our reports and maps beneficial to your work? 96.5% = YES:

	Yes	No	Percent of Respondents
Total	193	7	
Industry	30	0	15
Education	29	0	15
Consultant	17	0	8
Consulting company	25	0	12
General public	55	7	31
Government	37	0	18

Is all the geologic and mineral resources information that you <u>generally</u> need included in our publications? 8[illegible]% = YES

	Yes	No	Percent of Respondents
Total	178	28	
Industry	24	3	13
Education	28	5	16
Consultant	15	2	8
Consulting company	18	7	12
General public	58	8	32
Government	35	3	16

Electronic Data Coverages

Would you utilize DMR publications and geologic data bases by using a personal computer if the digital data were available? 60% = YES

	Yes	No
Total	114	74
Industry	19	7
Education	22	5
Consultant	11	5
Consulting company	17	7
General public	20	40
Government	25	10

Do you use a geographic information system (GIS) or have automated mapping capabilities? 32% = YES

	Yes	No
Total respondents (187)	60	127
Industry	14	16
Education	6	17
Consultant	3	13
Consulting company	8	14
General public	8	52
Government	21	15

Would you purchase maps and reports on CD-ROM? 54% = YES

	Yes	No
Total respondents (173)	93	80
Industry	15	8
Education	17	8
Consultant	7	8
Consulting company	16	6
General public	18	38
Government	20	12

If a system of "maps on demand" was operational, could you accept a 2-day delay in mailing of the maps? 89% = YES

	Yes	No
Total respondents (169)	150	19
Industry	26	0
Education	22	4
Consultant	10	3
Consulting company	19	1
General public	43	7
Government	30	4

How important is it that State Government educate the general public about geology, water, and mineral resources?

	Critical	Very Important	Important	Minor	Should Not Do
Total	92	81	31	6	1
Industry	14	10	6	0	0
Education	18	12	1	1	0
Consultant	6	7	2	1	0
Consulting company	12	10	3	0	1
General public	19	28	17	4	0
Government	23	14	2	0	0

Are there other topics upon which you think we should publish reports? 46% = YES

	Yes	No
Total respondents (82)	38	44
Industry	1	7
Education	7	2
Consultant	3	2
Consulting company	8	5
General public	11	20
Government	8	8

In what way?

Industry
- More aquifer characterization/ground-water studies

Education
- Coastal studies
- Surficial geology maps
- More general geology
- Geophysics

Consultant/consulting company
- More county and quadrangle geologic maps
- Hydrologic data
- Environmental project/data
- Soils
- Data for construction (karst and so on)
- Holocene/Quaternary geology
- More karst data

General public
- Soil types
- Geology related to pollution problems
- Geology/mineral resources

Government
- Mineral deposits and gemstones
- Hydrologic information/ground water
- Engineering geology
- Environmental geology
- Geologic maps for State at 1:24,000 scale
- Soils/surficial geology
- Geologic hazards
- Regulatory geology/3-D geologic models
- County-based geologic maps
- Region-based geologic maps

What information services do you require that are currently not provided?

Industry
- Site-specific data
- Updated geologic maps of Western Virginia, inclusive of county maps
- More mineral resources data
- Digitized topographic base
- More 1:24,000 quadrangle geologic mapping

Education
- More surficial geology maps

Consultant/consulting company
- More geologic quadrangle maps (1:24,000 scale, county, and so on)
- Site-specific data
- Digital topographic maps
- Hydrogeological data
- Subsurface boring/well data
- GIS information

General public
- Geologic map of State and subregion information
- Government
- GIS data
- Land-use data, water-use data, more 7.5-geologic quadrangles
- X-ray and petrographic analysis
- Ground water/water resources
- More county geologic maps
- 1993 State geologic map on CD-ROM
- Soil surveys
- More coastal plain data

What area(s) of DMR's information and product services should be improved upon?

Industry
- Digitized topographic information
- Data base for commodities in Virginia
- Regional studies—especially in areas where development has not occurred

Consultant/consulting company
- Access to data by CD-ROM
- Complete geologic mapping at 1:24,000
- More publications
- Hydrogeologic data (with geology)

General public
- More geological mapping at 7.5-minute scale
- Reprint—out of print publications
- Always use color in maps

Government
- Reprints of out-of-print reports
- More regional or county geologic reports
- Upgrade topographic maps every 2 years

FOCUS GROUP ASSESSMENTS OF USER NEEDS AND RECOMMENDATIONS FOR GEOLOGIC MAPPING

Focus Group Process

Geologic map users and stakeholders from six States (Md., Va., W.Va., Del., Pa., N.C.) and the District of Columbia were present at the Forum on Geologic Mapping Applications in the Washington-Baltimore Urban Area. Participants were organized into four working groups: (1) optimal land use, (2) ecosystems and water resources, (3) resources essential for the urban system, and (4) geotechnical applications of geologic maps. Participants in the focus groups were unaffiliated with either the USGS Geologic Division or State Geological Surveys. Each group was led by a meeting facilitator who, like the participants, was unaffiliated with either the USGS Geologic Division or State Geological Surveys. The focus groups were designed to solicit unfiltered input by external stakeholders into the design of Federal and State geologic mapping activities and products in the Washington-Baltimore urban area. The following four sections contain transcriptions from hand-written sheets produced by each of these groups. Each group met independently, as reflected by differences in the organization of their reports. A representative from each group presented their report to the whole forum, with time for open discussion.

Optimal Land Use

Reporter: Lindsay McClelland,
National Park Service
Meeting Facilitator: Jonathan J. Dillow, USGS,
Water Resources Division, Baltimore, Maryland

QA/QC and Standardization

Geologic mapping should be produced or developed on the basis of a set of agreed-upon criteria meeting QA/QC standards so that products reach a specified level of professionalism. Metadata, reports and project information, standardized data categories, sampling locations, temporal sampling frequency, universal horizontal/vertical datum controls, and examples of proper and improper applications should ensure appropriate data use and interpretation by the geologic community and the public.

Map Scales

There is a demand for geologic mapping at a variety of spatial scales, depending on the interest of the user. Demands for mapping conforming with the standard 7.5-minute quadrangles and with different political boundaries will both exist. Mapping efforts should focus on satisfying the need to produce products at varying scales and on the ability to combine digital maps, which can conform to any boundary.

Digital Format

Maps and related attributes should be made available in digital format—which should include a variety of format options, metadata sets, and a user friendly format. They should be available on Internet, on CD, and through cooperative ventures that would make public access easier.

Customers

Customers for geologic data must be broadly defined as anyone making a land-use decision. Customers' input must be sought several times during data collection and the mapping process. Customer input should be used to develop interpretation of geologic information that is suited to user needs and is of the appropriate technical level.

Derivative Mapping

Producers of geologic maps need to present data but also analyses and interpretations for professional and non-professional users. Such products should include multiplatform data or a common, digital base of standard format, including geochemical, engineering, geologic hazard, and water and mineral resource characterization. In this way, derivative mapping (including geochemistry, engineering, hazards, and so on) may facilitate reasonable land-use planning decisions based on the integration of multiplatform (biologic, hydrographic, and geologic) information.

- Multiagency input from ecoregion mapping.
- Combine data from multiagency sources.
- Better correlation, including vertical integration, between maps.
- Assessment of maps with respect to uncertainties and determination of error tolerances by use/user.

Ecosystems and Water Resources

Reporter: Robert P. Wintsch, National Science Foundation
Meeting Facilitator: Lyn E. Dellinger, Process Improvement Associates, Arlington, Virginia

Standard Terminology

It is very important for the geologic community to standardize its use and meaning of terminology. We could adopt one of the existing standardized terminologies such as the American Society of Testing Materials (ASTM) soil classification system (formerly Unified Soil Classification System) or we could publish our own. However, for the resulting terminology to be most useful, the terminology we use needs to mean exactly the same thing to each person mapping in the field or using maps in the office. For example, silt and clay are often used interchangeably and incorrectly. It is almost impossible to guess how much sand is in a "sandy clay." Similar standardization should be used for the terminology of rock types. ["Lack of standard terminology is a detriment to proper use of geologic maps."]*

Brittle Structures—Fractures, Joints, Faults

Geologic maps should show the orientation, dimension, opening, and density of all fractures, joints, minor faults, and major faults. Rationale: Fracture information is important for permeability of ground water, pollutants, and radon.

Surface Hydrology

Runoff in urban density zones is strongly affected by the creation of artificial, impervious surfaces (sidewalks, roads, driveways). Also, data on watershed boundaries, stream gauge locations, and other stream characteristics like stream depths and locations of rapids and waterfalls are useful. ["In urban zones the run-off problems are immense."]*

Enhanced Geologic Maps and Enhanced Delivery Systems

Enhanced geologic maps are necessary from the standpoint of full-color, large-scale maps with enhanced data of all related features. This "enhanced data" should include mineral modal and bulk chemical compositions, grain size and sorting, and engineering properties of all mapped units. These data should be made available in a digital format and internet accessible for use in various GIS systems in Federal, State, local, and private land-planning agencies. ["Geologic maps should have more detailed descriptions of map units and site-specific information related to water and other issues. Using a GIS system, the user could download specific layers, not necessarily the whole ball of wax."]*

Ground-Water Hydrology

Ground-water aquifer depletion and recharge rates need to be made available on maps, along with historic, present, and future conditions for ground-water suppliers and public officials faced with balancing developers' plans with the public interest. Additional ground-water data should include background water quality, information on lithology and water-chemistry interaction by rock unit, ground-water flow including volume and direction, and the location of waste sites. ["Recharge rates should be made available on maps where the data are available. Background water quality, interaction between water and rocks, and direction of flow are also useful."]*

GPS and Geophysical Data: Topographic Maps

Topographic maps should have a GPS data base, with GPS stations located. Rationale: The topographic survey is the repository of the XYZ coordinates of our land surface. A very central piece of background information for seismic hazard assessment is the change of location of monuments with time. The USGS has many monuments for hydrological data collection, and some of these could be used as GPS monuments. ["Stream gauges should have precise locations as an important component of basic information. The USGS should develop a background GPS network."]*

Karst Features

Karst and associated features need to be mapped and documented because of their important impact on manmade facilities.

Ecological Data

A number of ecological parameters should be compiled in conjunction (as overlays) with a geologic map base. These ecological features are likely controlled by the geologic formation with which they are associated. Suggested opportunities include critical ecological areas, wetlands, coastal zones, and rare ecosystems. Information would be used for site assessments, land-use planning, and environmental protection. ["Although geologists may not be the best people to collect these data, some general information could be captured during geologic mapping, such as location of wetlands and so on."]*

Educational Maps

Maps compiling the locations of sites of geological, mineralogical, and fossil interest and of historical and modern waste sites should be produced for schools, hobbyists, economic development groups, and tourism agencies. ["Perhaps a GIS layer for information that could be digested by K-12."]*

Hazards Mapping

It is very important to compile data about geologic hazards. For example some geologic formations are closely associated with slope stability failures at slopes having vertical-to-horizontal ratios greater than 1:4. Where these units crop out within a 7.5-minute quadrangle, they should be identified. Other examples are sinkholes, colluvium/unstable slopes, previous mining activities, shrink-swell soils, and hazardous or solid waste sites. ["Some formations are susceptible to slope failure, sinkholes, and so on."]*

*Additions in brackets [ ] are from the presenter's oral remarks.

Resources Essential for the Urban System

Reporter: Page A. Herbert, Redland Genstar, Inc.
Meeting Facilitator: Dennis A. VanLiere, Process Improvement Associates, Arlington, Virginia

1. Make all previously completed maps available (in print, on paper). Digitize existing and new maps for release, with complete index and supplemental supporting data, on both paper and magnetic/CD media.
2. Provide background data to indicate levels of accuracy and derivation of map basis (outcrops, chemical parameters, boundary uncertainty) as supplement.
3. Cultivate, through outreach to public, a funding base, distinct from technical user base.
   - Get easy data out fast, first.
   - Use a comprehensive approach.
4. Re-think elements of the basic product (that is, 7.5-minute geologic maps)
   - Provide more information on fieldwork and decision process for identifying geology.
   - For urban areas, reconsider appropriate scale, detail, and boundary definition of geologic units.
5. These points focus on our desire to have the ability to integrate both new and existing resource information into standard formats:
   a. Coordination between agencies/levels of government to enable integration of different kinds of information.
   b. Coordinate systems and elevation datums must be coordinated (at transitions).
   c. The goal of this is to allow—
      (1) In digital format, the ability of the user to generate custom maps.
      (2) In printed format, the publication of atlas series products.
6. Focus on the need to provide more detailed products in the following categories:
   - Watershed/drainage determination.
   - More detailed overburden products.
   - Fracture trace maps.
   - Land-use maps.
   - Overburden maps (updated).
   - Soils maps (especially with engineering properties emphasis).
   - Updated topography.
   - Urban infrastructure (for example, location of utilities).

Geotechnical Applications of Geologic Maps

Reporter: Eric Eisold,
Woodward Clyde Consultants
Meeting Facilitator: Berwyn E. Jones, USGS,
Water Resources Division, Denver, Colorado

Basic Geologic Data—Surficial and Bedrock Geology

In addition to geologic data traditionally provided on geologic maps, this group would like more information. At a minimum, this should include—
- More strike and dip measurements.
- Surface and bedrock geology.
- Thickness of overburden (residual soils).
- Depth to bedrock (sediments overlying bedrock).
- Geologic structure of bedrock and soils.
- Block diagrams.
- More cross sections.

These categories should be standardized for presentation on geologic maps.

Geotechnical Data

Every geologic map should present relevant geotechnical information on the surface and bedrock geology. Some of this information can be presented as footnotes, annotations, and tables. Such data should, ideally, include—

- A table summarizing significant engineering properties of each mapped unit (for example, unconfined compressive strength, relative density, unit weight, friction angle, cohesion, Atterberg limits).
- Descriptions of soil and rock units (including residual soils) in accordance with American Society of Testing Materials (ASTM) and International Society for Rock Mechanics (ISRM) standards.
- Significant natural and manmade hazards, such as landslides, karst susceptibility, subsidence, shrink-swell potential, fill zones, contamination, abandoned mine workings.
- Significant geotechnical test boring locations.
- Geophysical and seismic data.

Presentation/Delivery Systems

Based on the needs assessment for geotechnical applications of geologic mapping, the following recommendations are being presented:

- Digital format should include multiple overlays of various geologic, hydrologic, geotechnical, and cultural features.
- Delivery system for the digital formats should be the World Wide Web as well as traditional methods. They should be available in both technical and layman's versions. Online help should be available for both versions.
- 7.5-minute mapping is the preferred or standard recommended, but specific projects may require scale to be tailored to needs.

Hydrogeologic Information

As a part of the digital format, there should be several layers of hydrogeologic information including—

- Ground-water elevations.
- Ground-water hydraulic properties.
- Recharge areas.
- Well-log data (including shallow wells).
- Geochemical data.
- Water-quality data.
- Pollution-potential data.

Educational Tools (Schools and Individuals)

1. Access to traditional and new modes (WWW) of distribution (quickly).
2. Online help and answers to frequently asked questions (FAQ); realistic references and their local sources.
3. Availability of data sets for schools (investigations) and community issues.
4. Location of classic sites (outcrops) within the mapped area (preservation and observation).
5. Present data for teacher utilization for classroom activities.
6. Historical utilization of past map models (top 10, USGS folio series, "Nature To Be Commanded...").

Historical, Physical, and Cultural Features of Significance

1. Historical data sets (maps, case studies, logs, hazards, anthropomorphic changes (manmade)).
2. Cultural features (points to past land use, landmarks).
3. Physical features:
   - Buried land forms (stream valleys).
   - Surface (drainage divides, watersheds).
4. Physical geography of the quadrangle (highlights).

RESPONDING TO USERS' NEEDS FOR GEOLOGIC INFORMATION—WASHINGTON-BALTIMORE AREA

J. Wright Horton, Jr., U.S. Geological Survey
Emery T. Cleaves, Maryland Geological Survey

This forum is one of several that have been sponsored by the National Cooperative Geological Mapping Program, and co-convened by one or more State Geological Surveys and the U.S. Geological Survey, to assess regional needs for geologic map information. It is the first such forum to produce an unfiltered assessment of geologic mapping needs from focus groups comprised entirely of users and stakeholders unaffiliated with either the USGS Geologic Division or State Geological Surveys who produce most of these maps. [Stakeholders within the State Geological Surveys and the USGS Geologic Division, including those from various programs that require and support activities of the geologic mapping teams, have other avenues for expressing their needs.]

The recommendations, by design, were based on needs rather than on practical considerations of implementation. Members of the focus groups were unencumbered by practical limitations on geologic mapping agencies such as current commitments, program directions, budgets, staffing, and organizational structures. Their recommendations provide ambitious goals and directions, although realistically, some recommendations will not be easily achieved or even achieved at all. Expectations should not be unrealistically high. That being said, we will do our best to address the recommendations within our purview to the extent that we can in cooperation with partners at all levels. This report will serve as a guide to the needs of the Washington-Baltimore urban corridor user community.

In reflecting on the input from the panels and focus groups, our attention was drawn to several major themes:

(1) Digital Geologic Maps—The demand for digital geologic map information is strong, diverse, and far exceeds current production. This in no way diminishes the need for printed (paper) geologic maps. Both digital and printed geologic maps are needed throughout the region.

(2) Map Scales—Geologic maps at all scales are useful, depending on the application. Most users want as much detail and precision as possible, especially at 1:24,000 scale.

(3) Additional Information—Would increase the value of geologic maps and (or) supplementary layers, especially on (a) interpretations (at different levels of sophistication) and error limits, (b) brittle structures (fractures, joints, minor and major faults), (c) geotechnical data and site-specific information where available, (d) regolith thickness, and (e) water-related information.

(4) Derivative Maps and Multiple Geology Layers—Are useful and should be user friendly.

(5) Standardization—Is needed for (a) descriptive terminology and (2) formats (for folio series, for digital maps).

(6) Rapid Availability—Is needed for all geologic maps, ranging from old (none should be "out of print!") to speedy release of new data, whether printed on paper, on CD-ROM's, or on the internet.

Meeting these needs for detailed geologic maps with additional layers of information throughout the region would require decades at current production rates. Unless there are substantial increases in funding and staffing, meeting the identified needs will require long-term State and Federal commitments to sustain coordinated geologic mapping activity and expertise on the regional geology in the Washington-Baltimore area and along the Mid-Atlantic urban corridor.

APPENDIX 1. POSTER SESSION

ORGANIZATIONS REPRESENTED BY POSTER PRESENTATIONS

Carroll County (Md.) Government
Loudoun County (Va.) Government, Office of Mapping and Geographic Information
Maryland Geological Survey
Pennsylvania Geological Survey
U.S. Geological Survey Biological Resources Division
- Leetown Science Center (W. Va.)
- Patuxent Wildlife Research Center (Md.)

U.S. Geological Survey Geologic Division
- Eastern Region National Cooperative Geologic Mapping Team, USGS
- Eastern Region Mineral Resource Surveys Team, USGS

U.S. Geological Survey National Mapping Division, Mapping Applications Center (MAC)
U.S. Geological Survey Water Resources Division, Md.-Del.-D.C. District
Virginia Division of Mineral Resources
Virginia Extension Service, Loudoun County Office
Washington Metropolitan Area Transit Authority

ABSTRACTS

[Poster presenters were given the option of submitting abstracts]

Using Space/Time Transformations to Map Urbanization in the Baltimore-Washington Region

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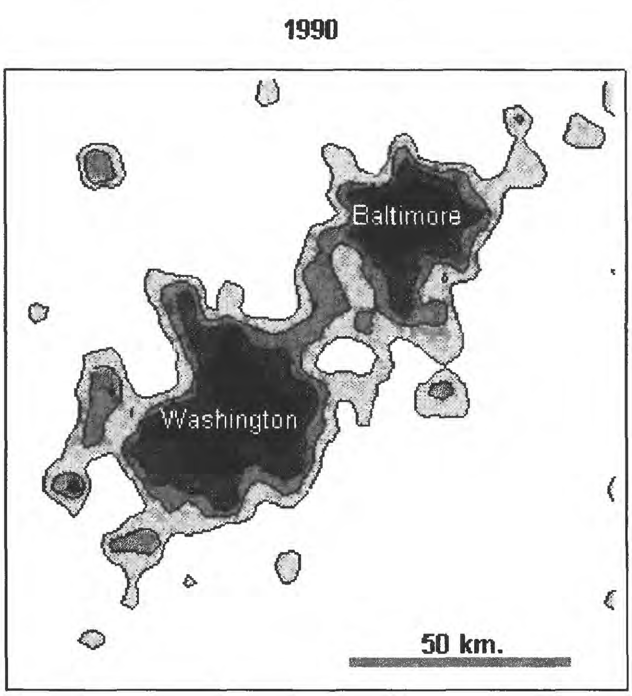
During the past year, researchers at the U.S. Geological Survey have been using historical maps and digital data for a 168- by 220-km area of the Baltimore-Washington region to produce a dynamic data base that shows growth of the transportation system and built-up area for 270-m grid cells for several years between 1792 and 1992. A "Mathematica" package was developed that spatially generalizes and temporally interpolates these data to produce a smoothly varying urban intensity surface showing important features of the 200-year urban process.

The boxcount fractal dimension of a power-2 grid pyramid was used to determine the most appropriate level of spatial generalization. Temporal interpolation was then used to predict urban intensity for 4,320-m cells for 10-year periods from 1800 to 1990. These estimations were spatially interpolated to produce a 1,080-m grid field that is animated as a surface and as an isopleth (contour) map. This technique can be used to experiment with future growth scenarios for the region, to map other kinds of land cover change, and even to visualize quite different spatial processes, such as habitat fragmentation caused by climate change.

For the animation, see: http://geog.gmu.edu/gess/classes/geog590/gis_internet/ldecola/baltwash/



Sinkholes and Karst-Related Features within the Baltimore-Washington Urban Corridor: Frederick and Winchester 30′ × 60′ Quadrangles, Virginia, West Virginia, and Maryland

Randall C. Orndorff and Scott Southworth,
U.S. Geological Survey, 926A National Center,
Reston, VA 20192

Sinkholes, caves, pinnacled bedrock, and other karst-related features occur in four distinct areas in the Virginia, West Virginia, and Maryland part of the central Appalachians—the Great Valley, the northwest part of the early Mesozoic Culpeper basin, the Frederick Valley, and the western Piedmont east of the Frederick Valley. We are currently mapping the distribution of carbonate rock and karst features within the Frederick 30′ × 60′ quadrangle as part of a regional geologic study of the Baltimore-Washington urban corridor. Karst in these areas poses potential environmental and engineering hazards associated with industrial and urban development.

The long agricultural history of the area and the recent increase in industrial and urban development have increased the potential for ground-water contamination. Ground water can be rapidly transported in limestone and dolostone through joints, faults, and bedding planes enlarged by solution. The complex hydrogeologic systems associated with karst create difficulties in predicting the rate and direction of ground-water movement. Potential sources of contamination include agricultural runoff, industrial pollution, leaking underground storage tanks, regional landfills, sinkhole dumps, and private septic systems. Also, ground-water contamination can affect surface water quality where it rises to the surface at springs.

Sinkhole collapse, which involves the sudden vertical mass movement of residuum and bedrock, is a hazard in areas of carbonate bedrock in the central Appalachians and needs to be considered in engineering and geotechnical studies and in land-use planning. Both natural processes and man's influence contribute to the risk. For example, a common cause of collapse is a drop in the water table due to extended droughts or excessive pumping of ground water. In the study area, subsidence typically occurs over long periods of time by solutional enlargement of joints, faults, and bedding planes. However, sudden collapse of residuum and bedrock does occur. Since 1992, extensive property damage has resulted from collapse sinkholes in Clarke County, Va., and Frederick and Carroll Counties, Md.

Factors that control sinkhole development include lithologic characteristics, fracture density in bedrock, and the proximity of carbonate rocks to streams. Sinkholes tend to be more abundant and larger in size (depth and diameter) near entrenched streams where the hydraulic gradient is steepened and the rate of ground-water flow is increased. However, in areas with poor surface drainage, lithologic characteristics are the most important factor controlling sinkhole development.

Significant portions of the Baltimore-Washington urban corridor are underlain by carbonate rock but exhibit no surface expression of subsidence features. Here, too, karst processes are active. In these areas, karst is expressed by poorly developed surface drainage, as well as minor solutional sculpting of exposed bedrock. Areas such as these present a variety of potential problems for land users, including relatively rapid movement of contaminated ground water, and difficulties in engineering building foundations due to differential compaction, soil piping, and collapse of subsurface cavities.

Lithogeochemical Map Units and Water Quality Patterns in the Chesapeake Bay Watershed

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Reston, VA 20192

Geologists and hydrologists have long noted close relationships between major-element rock chemistry, as expressed by rock type, and the chemistry of the contained waters. Generally, for example, limestones yield hard, alkaline waters, whereas black shales, carbonaceous schists, and peat yield reducing, oxygen-poor waters. Quartzose sediments and rocks have little capacity to neutralize acid or to buffer waters. Maps of Maryland and eastern Virginia, using a lithogeochemical classification scheme, show regional patterns of predicted water quality effects and areas of reduction and elimination of nitrate pollutants.

A lithogeochemical rock classification, based on the predicted ability of Mid-Atlantic rocks and sediments to buffer and interact with their contained waters, has shown a significant degree of correlation with observed water chemistry in four areas previously studied by aqueous geochemists in and near the Chesapeake Bay watershed. On the seaward side of the mouth of Chesapeake Bay, organic deposits mapped in Cape Charles and Norfolk Counties, Va., reduce and eliminate nitrates infiltrating from above. In Frederick County, Md., limestones in the Frederick Valley have the highest acid neutralizing capacity, followed by Catoctin Formation metabasalt; the intervening phyllite and quartzite (resistates) are essentially nonreactive with the acidic stream water. East of Chesapeake Bay, relatively unweathered greensand in Kent County, Md., reduces and eliminates nitrates infiltrating through highly oxidized greensand and quartz sand and gravel above.

Digital and Open-File Products of the Pennsylvania Geological Survey

Helen L. Delano, Christopher D. Laughrey, and Thomas Whitfield,
Pennsylvania Department of Conservation and Natural Resources, Bureau of Topographic and Geologic Survey, P.O. Box 8453,
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The Wells Information System (WIS), developed in the Subsurface Geology Division of the Pennsylvania Geological Survey is an ARC/INFO and ORACLE data base that will manage the Survey's collection of well records from over 300,000 oil and gas wells drilled in the State since 1869. The data base contains information about well locations, well completion data, interpreted stratigraphy, petroleum production, geophysical well logs, and well cuttings and core sample. The purpose of WIS is to provide the public with an automated file cabinet and research tool. WIS provides the citizens of Pennsylvania with a detailed interactive data base for analyzing and evaluating the status of drilling, oil and gas production, and subsurface stratigraphy in Pennsylvania.

Two other data bases track the Commonwealth's water wells. Much of the data are field verified; some are obtained from drillers reports. Some information is available on ground-water quality.

Other digital data collections that are available or being developed include Non-Coal Mineral Producers in Pennsylvania, Earthquake Epicenters in and near Pennsylvania, and Sinkholes and Karst Features.

Many of our recent reports and maps are now released on open-file. Recent products include (1) Surficial Geology in the Allentown Area and (2) Surficial Geology of Southern York and Lancaster Counties. These are available as black-and-white copies prepared on the 7.5-minute topographic base.

Karst features mapped on 7.5-minute quadrangles are available for 14 counties, mostly in the Great Valley and southeastern Pennsylvania.

A number of other reports and maps on a variety of topics and areas are also available on open-file. A current list and ordering instructions will be available at this forum or can be obtained by contacting the Survey at P.O. Box 8453, Harrisburg, PA 17105; phone (717)787–2169. More information on digital data files is available from the same address.

Geologic Map of the Washington West 30′ × 60′ Quadrangle, District of Columbia, Virginia, and Maryland

Peter T. Lyttle, John N. Aleinikoff, Avery Ala Drake, Jr., Albert J. Froelich, J. Wright Horton, Jr., Gregorius Kasselas, Lucy McCartan, Robert M. Mixon, Arthur E. Nelson, Louis Pavlides, and Robert E. Weems, U.S. Geological Survey, 926A National Center, Reston, VA 20192

The Washington West 30′ × 60′ quadrangle covers an area of approximately 4,884 km^2 in and west of the Washington, D.C., metropolitan area. The eastern part of the area is highly urbanized, and rural fringe areas to the west are rapidly being developed. The area lies entirely within the Chesapeake Bay drainage basin and mostly within the Potomac River watershed. It contains part of the Nation's main north-south transportation corridor east of the Blue Ridge Mountains. Extensive Federal land holdings in addition to those in Washington, D.C., include the Marine Corps Development and Education Command at Quantico, Fort Belvoir, Vint Hill Farms Station, the Naval Ordnance Station at Indian Head, the Chesapeake and Ohio Canal National Historic Park, Great Falls Park, and Manassas National Battlefield Park. The quadrangle contains most of Washington, D.C.; part or all of Arlington, Culpeper, Fairfax, Fauquier, Loudoun, Prince William, Rappahannock, Stafford, and Clarke Counties in northern Virginia; and parts of Charles, Montgomery, and Prince Georges Counties in Maryland. This geologic map is intended to serve as a foundation for applying geologic information to problems involving land-use decisions, ground-water availability and quality, earth resources such as natural aggregate for construction, assessment of hazards, and engineering and environmental studies for waste-disposal sites and construction projects. This 1:100,000-scale map is largely based on more detailed geologic mapping at the scale of 1:24,000 and serves as an index to such information where it is available.

The Washington West quadrangle spans four geologic provinces. From west to east these provinces are the Appalachian Blue Ridge, the early Mesozoic Culpeper basin, the Appalachian Piedmont, and the Atlantic Coastal Plain. The Blue Ridge province, which occupies the western part of the quadrangle, contains metamorphic and igneous rocks of Middle Proterozoic to Early Cambrian age exposed in the Blue Ridge anticlinorium. Middle Proterozoic rocks in the hinge area of the anticlinorium are mostly granitic, although older metasedimentary rocks are also present. Late Proterozoic granitic rocks of the Robertson River Igneous Suite intrude the Middle Proterozoic rocks. The Middle Proterozoic rocks are nonconformably overlain by Late Proterozoic arkosic metasedimentary rocks of the Fauquier and Lynchburg Groups, which in turn are overlain by metabasalts of the Catoctin Formation. The Catoctin Formation is overlain by Late Proterozoic and Lower Cambrian metasedimentary clastic rocks of the Chilhowee Group, which consists of the Weverton Quartzite and overlying Harpers Formation.

Crystalline rocks of the Appalachian Piedmont province, which underlie the east-central part of the quadrangle, occur between the overlapping sedimentary units of the Culpeper basin on the west and those of the Atlantic Coastal Plain on the east. In this area, the Piedmont contains Late Proterozoic and lower Paleozoic metamorphosed sedimentary, volcanic, and intrusive rocks. Allochthonous melange complexes on the western side of the Piedmont are bordered on the east by metavolcanic and metasedimentary rocks of the Chopawamsic Formation, which has been interpreted as part of an early Cambrian(?) volcanic arc. The melange complexes are unconformably overlain by metasedimentary rocks of the Popes Head Formation. The Ordovician Quantico Formation is the youngest metasedimentary unit in this part of the Piedmont. Igneous rocks include the Garrisonville Mafic Complex, transported ultramafic and mafic blocks in melanges, monzogranite of the Dale City pluton, and Ordovician tonalitic and granitic plutons. Jurassic diabase dikes are the youngest intrusions. The fault boundary between rocks of the Blue Ridge and Piedmont provinces is concealed beneath the Culpeper basin in this quadrangle but is exposed farther south in Virginia.

The Culpeper basin of northern Virginia and Maryland is located in a belt of Late Triassic to Early Jurassic faultbounded troughs exposed in eastern North America from Nova Scotia to the Carolinas. These troughs, containing nonmarine Newark Supergroup strata, are generally in alignment with the structural grain of enclosing Paleozoic and Proterozoic metamorphic rocks. Lower Mesozoic rocks of the Culpeper basin unconformably overlie those of the Piedmont and Blue Ridge provinces in the central part of the map. The north-northeast-trending extensional basin contains Upper Triassic to Lower Jurassic fluvial, lacustrine, and playa clastic sedimentary rocks, mainly "red beds" and conglomerates. Lower Jurassic basalt flows are interbedded with the sedimentary rocks, and both Upper Triassic and Lower Jurassic strata are intruded by diabase of Early Jurassic age. The Bull Run fault on the west side of the basin is a major Mesozoic normal fault characterized by down-to-the-east displacement. It separates Culpeper basin rocks from those of the Blue Ridge province. An unconformity on Piedmont province rocks, which has been locally disrupted by normal faults, marks the east side of the Culpeper basin.

Sediments of the Atlantic Coastal Plain unconformably overlie rocks of the Piedmont along the Fall Zone and occupy the eastern part of the quadrangle. Lower Cretaceous deposits of the Potomac Formation (equivalent to the Potomac Group in Maryland and northward) consist of fluvial-deltaic gravels, sands, silts and clays. West of the Potomac River, these Cretaceous strata are capped by discontinuous gravel sheets of middle to late Tertiary and Quaternary age. East of the Potomac River, the Potomac Formation is unconformably overlain by marine sedimentary deposits of Late Cretaceous and early to late Tertiary age and by upper Tertiary nonmarine gravel, sand, and mud. Fluvial and estuarine terrace deposits of Pleistocene and latest Tertiary age flank the modern Potomac River. Faults of Tertiary to Quaternary age occur west and north of the river.

When released for publication this map will be available in digital form and will become part of the National Geologic Map Database.

Geology of the Fredericksburg 30′ × 60′ Quadrangle, Northeastern Virginia and Southern Maryland

Robert B. Mixon, Louis Pavlides,
David S. Powars, Robert E. Weems,
Stephen J. Schindler, and Wayne L. Newell,
U.S. Geological Survey, 926A National Center,
Reston, VA 20192

The Fredericksburg map encompasses parts of four different terranes—the Atlantic Coastal Plain, the Appalachian Piedmont, the early Mesozoic Culpeper basin, and the Blue Ridge anticlinorium. The Coastal Plain terrane, which constitutes the eastern half of the map area, is an eastward-thickening body of mostly unlithified Cretaceous (144 to 66 million years ago) and Tertiary (66 to 1.8 million years ago) sand, gravel, silt, and clay. Maximum thickness of these deposits in the easternmost part of the area is about 600 m (2,000 ft). Quaternary (less than 1.8 million years ago) sediments occur mainly as a steplike series of fluvial and estuarine terrace deposits that parallel the Rappahannock, Potomac, and Mattaponi Rivers. At the Fall Zone, near the inner edge of the Coastal Plain, a zone of en echelon, northeast-striking, northwest-dipping reverse faults places crystalline rocks of the Piedmont at a high angle over Coastal Plain strata of Cretaceous to Pliocene age (144 to 1.8 million years ago). Episodic faulting began at least as early as the Early Cretaceous and extended into middle and late Tertiary time.

The northeast-trending crystalline-rock terrane of the Piedmont lies between the more easily eroded strata of the Coastal Plain to the east and the Culpeper basin to the west. This terrane consists of metamorphosed sedimentary, volcanic, and plutonic rocks of Late Proterozoic (900 to 540 million years ago) and Paleozoic age (540 to 245 million years ago) and is commonly highly deformed. In the northwestern corner of the map area, Piedmont crystalline rocks are overlain with great angularity by thick continental deposits of the early Mesozoic Culpeper basin, a half graben that trends northeastward through the Virginia and Maryland Piedmont. In the map area, the basin fill is of Triassic age (245 to 208 million years ago) and consists of red and gray shale, siltstone, mudstone, sandstone, and conglomerate of fluvial and lacustrine origin. These sedimentary rocks thicken westward toward the Bull Run Mountain border fault and are intruded by thin to thick diabase sills and dikes of Jurassic age.

Late Proterozoic and Cambrian metabasalts and metasediments of the east limb of the Blue Ridge anticlinorium occur in the northwestern corner of the map area. The largest body of these rocks underlies Clark Mountain in the vicinity of Everona, Va. Other areas of Blue Ridge rocks that crop out include a small horst, well within the Culpeper basin, that forms "The Ridge" near Stevensburg, Va., and the relatively upthrown block west of the Culpeper basin border fault at Culpeper, Va.

Our map and the accompanying cross sections may be used to help determine the extent and thickness of aquifers and confining beds, areas of aquifer recharge, sources of natural aggregate including crushed stone and sand and gravel, sources of expandable clay, mineral resources, geotechnical properties of surficial materials and bedrock, and other geologic and hydrologic factors affecting land-use planning. In addition, our map delineates two major zones of faulting (Stafford and Mountain Run) that indicate late Neogene (less than 11 million years ago) movement and, therefore, affect the siting of large structures, such as nuclear generating stations and dams.

Geology of the Frederick 30′ × 60′ Quadrangle, Maryland, Virginia, and West Virginia

Scott Southworth, U.S. Geological Survey, Reston, Va., David Brezinski, Maryland Geological Survey, Baltimore, Md., and Randall Orndorff, Avery Drake, and William Burton, U.S. Geological Survey, Reston, Va.

Since 1989, the U.S. Geological Survey (USGS) and Maryland Geological Survey (MGS) have been cooperatively mapping bedrock and surficial geology at 1:24,000-scale within the Frederick 30-by-60 minute quadrangle; production of an ARC-INFO geologic map is planned for 1998. The Frederick quadrangle will be the northern part of a three 30-by-60-minute-quadrangle (1:100,000-scale) ARC-INFO data base that forms the core of the Washington-Baltimore urban corridor within the GOMAC Project of the Eastern Region National Cooperative Geologic Mapping Program.

The geology includes parts of the Coastal Plain, Piedmont, Blue Ridge, and Great Valley provinces of the central Appalachians. Bedrock ranges in age from Middle Proterozoic gneiss in the core of the Blue Ridge-South Mountain anticlinorium to Early Paleozoic shale in the core of the Massanutten synclinorium of the Great Valley, undated metamorphosed sedimentary and volcanic rocks in the Piedmont, and Early Mesozoic sedimentary strata and diabase of the Culpeper and Gettysburg basins. Collectively, these rocks constitute evidence for several events of continental collision and rifting.

Quaternary surficial deposits include alluvium, colluvium, and fluvial terraces. Saprolite of deeply weathered metamorphic rocks is restricted to the Piedmont. Carbonate rocks of the Great Valley, and Culpeper basin, Frederick Valley, and Westminster terrane of the Piedmont, have weathered to karst with lag gravels capping hillocks adjacent to sinkholes.

The geologic data base used in the 1:100,000-scale compilation consists of a detailed folio of maps that were produced for specific customers—16 maps at 1:12,000-scale, 6 maps at 1:24,000-scale, and 2 maps at 1:50,000- and 1:100,000-scale for the Loudoun County, Va., Department of Natural Resources and Soil Extension, and parts of 12 1:24,000-scale maps of the C&O Canal National Historical Park for the National Park Service. For site-specific investigations, all of the 32 7.5-minute quadrangles will be available as published color or open-file ozalid geologic maps by the USGS, MGS, Virginia Division of Mineral Resources, and West Virginia Economic and Geological Survey. A major objective of this project is to produce a simplified digital lithologic map to enable cooperative multidisciplinary studies of the relationship of geology to geotechnical properties of materials, soils, water, aggregate resources, and karst subsidence by county, State, and Federal Government agencies. In addition, general interest publications and field trip guides will form a component of outreach and education for this densely populated region.

Mid-Atlantic Geology and Infrastructure Case Study Project

Gilpin R. Robinson, 954 National Center, U.S. Geological Survey, Reston, VA 20192, and Valentin V. Tepordei, 983 National Center, U.S. Geological Survey, Reston, VA 20192

Continued population growth and urbanization, particularly in the urban corridors of the Eastern United States where existing infrastructure is deteriorating and needs maintenance and expansion, will generate huge demands for construction materials. Sand, gravel, and crushed stone are the materials with which our cities are built and are the dominant basic raw material of the economy. Current national production exceeds 2 billion tons of aggregate per year. On the basis of either weight or volume, aggregates account for over two-thirds of the approximately 3.3 billion tons of nonfuel minerals mined in the United States each year. This production trend and resource need will likely continue and grow in the future. These raw materials are indispensable to the maintenance and development of urban environments, and virtually all aggregate that is mined domestically is used locally. Because both geologic and economic market conditions dictate the locations where economically recoverable aggregate and construction raw materials may be produced, opportunities to meet the future demand of the construction industry will be controlled by the availability of the resource.

The successful integration of natural-resource information into land-use decisions is increasingly difficult as the competing needs for lands and resources become more numerous, complex, and urgent. In response to these issues, the aggregate industry has gone through significant changes over the last 30 years. However, a comprehensive analysis of the changes and trends is lacking. The identification of longer term trends and changes is largely anecdotal, and the comprehensive documentation of long-term regional resource production trends, material flows, and supply issues generally does not exist.

The high level of production of construction materials and the significant changes in resource and urban development that have taken place in the Mid-Atlantic region during the last 30 years provide insights into the likely future trends in other areas of the Nation.

The Baltimore-Washington urban corridor has been chosen for the case study because of the availability of a good resource information data base and because, with over 7 million people spread over 39 counties and the District of Columbia, the Baltimore-Washington urban corridor is one of the Nation's fastest growing metropolitan areas.

The case study area will cover the District of Columbia and parts of Maryland, Pennsylvania, Virginia, and West Virginia and will focus on the counties within 38° to 40° N. and 76° to 78° W.

The objectives of the regional case study are to—

- Identify the main geologic sources and locations of high-quality construction resources in the region.
- Document on a county basis, for the last 35 years, how much aggregate was produced and used in the region of study, who produces aggregate, who uses aggregate, and how much they consume.
- Analyze the resource production and demographic information to develop a sensitivity analysis of per capita trends, growth-based trends, and base-level trends for the region.
- Calibrate and validate a geographic information system (GIS) model for the region to develop a resource-demand forecasting tool.
- Analyze county-level management planning and the historic decision record to evaluate the effectiveness of planning in regard to aggregate resources. What comprehensive plans exist, what decisions regarding mineral development have been made, and who makes these decisions?

Anticipated products include the following:

- Digital data base with inventory of aggregate resources and time-series documentation of regional resource development trends, material flows, and infrastructure development history.
- Information manual identifying current resource producers in the region and the roles and responsibilities of State and county organizations and agencies involved with resource production, permitting, and regulation. The manual will also include summaries of relevant Federal, State, and county rules and regulations influencing resource-development decisions and activities.
- Analysis tools to forecast future aggregate resource demands.
- Documentation and analysis of emerging land-management and resource-availability issues.

Project Timetable: 3 years.

Cooperators and Collaborators:

- Maryland Geological Survey
- Virginia Division of Mineral Resources
- National Stone Association

Geology of the Waterford, Va., Quadrangle and Virginia Portion of the Point of Rocks Quadrangle and Its Socioeconomic Significance

William C. Burton, Geologist,
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The bedrock geology of the Waterford quadrangle and of the Virginia part of the Point of Rocks quadrangle consists of a portion of the Mesoproterozoic basement core and its cover sequence on the eastern limb of the Blue Ridge anticlinorium and the adjacent early Mesozoic Culpeper basin. The three major rock associations in this area are (1) Mesoproterozoic gneisses, which are extensively intruded by Neoproterozoic metadiabase dikes; (2) unconformably overlying Neoproterozoic and early Paleozoic metavolcanic and metasedimentary rocks; and (3) Upper Triassic sedimentary strata intruded by Early Jurassic diabase. The Triassic and Jurassic rocks are separated from the older rocks of the anticlinorium to the west by a major normal fault known as the Bull Run fault. Late Cenozoic surficial deposits of three major types unconformably overlie the bedrock—colluvium derived from Catoctin Mountain, terrace deposits of the Potomac River, and flood-plain alluvium of the Potomac River and its tributaries.

The bedrock formations have greatly varying hydrogeologic characteristics and water-well yields. The greenstones of the Catoctin Formation are impermeable and produce some of the lowest yields in Loudoun County. Immediately to the east the highest yields are found in the Triassic sedimentary rocks, specifically the karstic carbonate conglomerate of the Leesburg Member of the Balls Bluff Siltstone. At the south end of the map, the Leesburg Member underlies an area of rapid residential and commercial development on the northern outskirts of Leesburg, which will impact local ground-water quality and supply. The historic town of Waterford, underlain by the gneiss-dike complex, has the highest concentration of wells in Loudoun County, resulting in chronic water shortages. Rapid residential development and water-well drilling is occurring in the surrounding area.

The map area has a history of mineral-resource development, mostly occurring in the 1800's. Limonite (iron ore) was mined from Antietam Quartzite at Furnace Mountain, and thin marble layers in the Swift Run and Catoctin formations were quarried for agricultural lime and building material. Leesburg Member conglomerate was extensively used for agricultural lime, and immediately north of the map area this rock was quarried to make the distinctive columns of the Capitol Building.

APPENDIX 2. FOCUS GROUPS

GROUP 1. OPTIMAL LAND USE

Meeting Facilitator: Jonathan J. Dillow, USGS, Water Resources Division, Baltimore, Maryland

Michael Bowman, Tetra Tech, Inc.
Mustafa Cayci, Parson's Engineering Science
Anthony Creech, Resource International
Mark Eisner, Atlantic Geoscience Corporation
Marie Frias, National Park Service, C&O Canal National Historical Park
Normand Goulet, Northern Virginia Planning District Commission
Dan Hatch, Fauquier County Government, Virginia
Robert Jones, Frederick Ward Association
Carla Kertis, U.S. Department of Agriculture
Lindsay McClelland, National Park Service, Geologic Resources Division
Remo Nardini, George Washington University
Hasan Qashu, George Washington University, Center for Applied Environmental Technology
Mike Roberts, Carroll County Government, Maryland
John Sauer, USGS, Biological Resources Division, Patuxent Wildlife Research Center
John Seibel, Coastal Environmental Services
Sean Smith, Maryland Department of Natural Resources, Watershed Restoration Division
Larry Stipek, Loudoun County Office of Mapping and Geographic Information, Virginia
Ian Thomas, USGS, Biological Resources Division, Patuxent Wildlife Research Center
John Young, USGS, Biological Resources Division, Leetown Science Center

GROUP 2. ECOSYSTEMS AND WATER RESOURCES

Meeting Facilitator: Lyn E. Dellinger, Process Improvement Associates, Arlington, Virginia

LaJan Barnes, Environmental and Turf Services, Inc.
Mike Bialousz, Lord Fairfax Planning District Commission, Virginia
Elizabeth Burkhard, Leetown Science Center, USGS, Biological Resources Division
Molly Gary, Maryland Department of the Environment
Paul Jacobson, Langhei Ecology, LLC
William Petrie, Calvert Manor Corporation
Scott Phillips, USGS, Water Resources Division, Md.-Del.-D.C. District
Ann Samford, Virginia Geotechnical Services
Robert Shedlock, USGS, Water Resources Division, Md.-Del.-D.C. District
Mike Slattery, Maryland Department of Natural Resources, Wildlife and Heritage Division
Marcia Smith, Maryland Department of the Environment
Chris Stephan, Schnabel Environmental Services
Nissa Thomsen, USGS, Biological Resources Division, Leetown Science Center
Keith Van Ness, Montgomery County Department of Environmental Protection, Maryland
Hamé Watte, Water Resources Research Center
Wallace White, Howard County School System, Maryland
Robert Wintsch, National Science Foundation, Division of Earth Sciences

GROUP 3. RESOURCES ESSENTIAL FOR THE URBAN SYSTEM

Meeting Facilitator: Dennis A. VanLiere, Process Improvement Associates, Arlington, Virginia

Mupesh Batel, Maryland State Highway Administration
Ken Carter, Maryland Department of the Environment
Kimberly Davis, Northern Virginia Planning District Commission
Gerald Eidenberg, Eidenberg Geoscience
Bill Frost, Arlington County Public Works, Virginia
Page Herbert, Redland Genstar, Inc.
Randah Kamel, Maryland State Highway Commission
Eric Klein, Century Engineering
Will Logan, George Washington University, Department of Geology
David Martin, Maryland State Highway Administration
Nyambi Nyambi, National Capital Planning Commission
Katie Stanton, Rappahannock-Rapidan Planning District Commission, Virginia
Gerry Stirewalt, Geological Systems Consultants
Linda Unkefer, Fauquier County Government, Virginia
David Verardo, University of Virginia, Department of Environmental Sciences
John Wolf, Exploration Research, Inc.

GROUP 4. GEOTECHNICAL APPLICATIONS OF GEOLOGIC MAPS

Meeting Facilitator: Berwyn E. Jones, USGS, Water Resources Division, Denver, Colorado

Mike Bailey, U.S. Army Corps of Engineers
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PANEL DISCUSSIONS—
ABSTRACTS OF COMMENTS

Urbanization and Water Quality

Creating Durable Habitats

Geologic Information for the Urban System

Natural and Induced Hazards—
Avoidance and Remediation

RESULTS OF STATEWIDE USER SURVEYS

FOCUS GROUP ASSESSMENTS OF
USER NEEDS AND RECOMMENDATIONS
FOR GEOLOGIC MAPPING

Optimal Land Use

Ecosystems and Water Resources

Resources Essential for the Urban System

Geotechnical Applications of Geologic Maps

RESPONDING TO USERS' NEEDS
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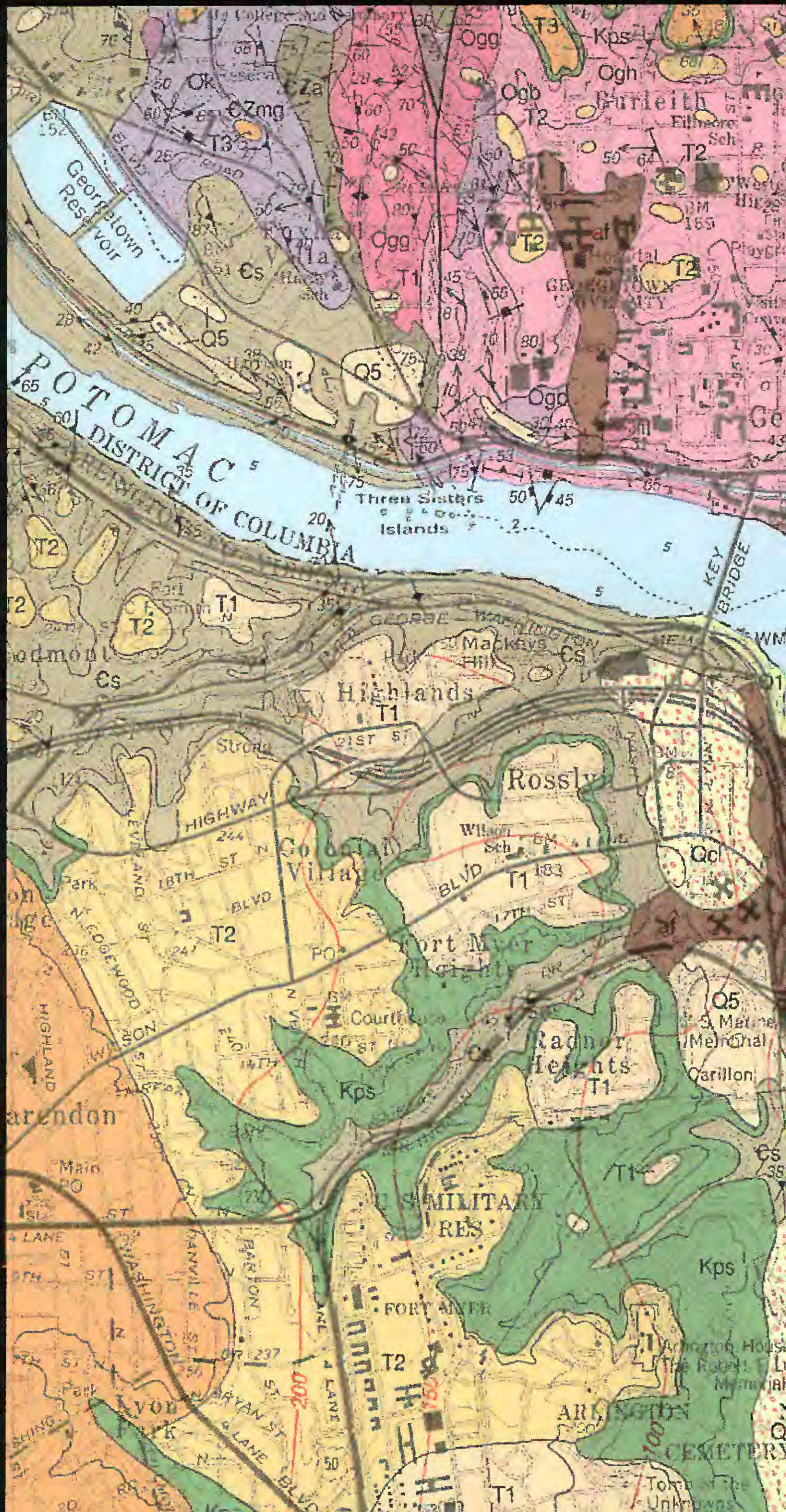

ISBN 0-607-88721-4
9 780607 887211