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D. Briane Adams, Katrina Burke, Bruce Hemingway, Jeff Keay, and
Michael Yurewicz, compilers

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For additional information write to:

D. Briane Adams
U.S. Geological Survey
3850 Holcomb Bridge Road
Suite 160
Norcross, Georgia 30092

Copies of this report may be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, Colorado 80225-0286

PREFACE

Why the Appalachians? A U.S. Geological Survey Integrated Science Planning Effort

Some of nature's most magnificent creations on Earth are the picturesque landscape and the terrestrial and aquatic inhabitants of the Appalachian Mountains of the Eastern United States. Mother Nature has been kind to the region but man, often, has not. The Appalachian mountains and valleys have been home to a variety of human cultures, dating back approximately 12,000 years. A series of Native American peoples, including most recently the Cherokee Nation, inhabited the region prior to European settlement which began in the 1600's. All of these peoples have had the desire to reap the benefits of the land.

Current and historic use of the land ranges from mineral extraction to agricultural development to timber production to industrial and residential development, all of which have now threatened the landscape. Many individuals and organizations desire to save the awe and beauty of the Appalachians for the generations to come, in a way that is environmentally and economically sustainable. They have tried for years to raise alarms that this area is threatened and worth the attention of all who are interested in an effort of restitution and preservation. Residents, environmental groups, land managers, scientists, business groups, and the multitude of visitors who pass through the national parks and other public lands located within the Appalachians have raised these same alarms. There is a need to not only identify the issues resulting from anthropogenic pressures on the landscape, but also to collect the information and conduct the science that will allow land managers and policy makers to become better informed and better able to execute their responsibilities.

The issues are many—air quality, sustainable development, threatened and endangered species, invasive species, landscape fragmentation, watershed modification, ground-water contamination, mineral extraction, cultural and economic impacts—to list just a few. An important awareness has developed in the past decade .... individuals, businesses, government agencies, universities, and private groups are beginning to work together to preserve the landscape of the Appalachians for not only the economic future of human residents and the natural environment for endemic species, but also for the many millions of visitors who come to enjoy the majestic scenery. One such group is the Southern Appalachian Man and Biosphere (SAMAB) program, founded in 1988 as a cooperative of Federal agencies that collaborate to provide information necessary for solving issues related to their natural resource missions and responsibilities in the Southern Appalachians. This cooperation has resulted in numerous efforts to identify and correct longstanding problems and to improve management practices in the region. The most comprehensive of these efforts was the Southern Appalachian Assessment (SAA), which was completed in 1996. The assessment provided feedback on the current status of the resources of the area and identified many issues that needed to be addressed. To date, there has been no comprehensive effort to follow up and address the issues identified. About the same time that the SAA was being completed, the U.S. Geological Survey (USGS) initiated an effort to develop the Southern Appalachian Critical Ecosystem Program (SACEP), a solicited proposal for funding under the then National Ecosystem Program, which had initiated work in other parts of the United States, most significantly in southern Florida. The SACEP continues to remain unfunded. Since that time, the USGS has been reorganizing both administratively and programmatically. During this reorganization process, the USGS has concentrated on conducting science in an integrated and multidisciplinary manner. As a result, a number of national issues of concern have been identified, with several geographic areas and landscapes designated as specific focus areas for scientific study. Initially, the Appalachians were not considered as one of these specific areas of focus. USGS managers now have become convinced that the region should be reconsidered as a focus area for scientific study. Subsequently, USGS scientists and managers from all disciplines throughout the USGS gathered at a workshop in Gatlinburg, Tennessee, from October 22-26, 2001, to share data, scientific results, and ideas. An attempt was made to establish an understanding about the current status of science efforts, to develop new collaborative opportunities, and to further scientific understanding of the issues and the impacts on the earth resources of the Appalachians. As a result of this workshop, a draft "science opportunities" document is currently under development in an effort to help set USGS priorities for investment of resources for the foreseeable future. In developing this document, issues and gaps in scientific understanding are being identified. The plan will not be successful, however, if developed from within the USGS alone. It is critical that all USGS partners provide their voice in identifying issues and needs for science information in this region. A second workshop scheduled for early 2002 will invite the participation of USGS partners to not only critically review the draft integrated science opportunities document, but to come with their issues and needs as identified from their perspectives. The needs of USGS partners will be incorporated into a final document that will be used as a guide by the USGS to focus and seek additional resources for the future. The document on Appalachian area science opportunities will be made available to all who have an interest in the USGS efforts in the Appalachian region. A new USGS website is being developed for the Appalachian region — http://www.AppalachianRegionScience.usgs.gov. At this website, you can find data and information on current and past USGS research in the Appalachian region, and proceedings from the October 2001 USGS workshop. The website will also house the draft science opportunities document which will be available for review and input. You can also find links to other supporting websites with information on Appalachian region resources. We invite you to provide additional internet information links that can be added to the website.

In summary, the workshop was organized to bring together USGS scientists of all disciplines to not only identify their current areas of research in the Appalachian region but to allow them the opportunity to become familiar with whom they may collaborate in future work. We hope that the information presented at the workshop and in these proceedings will not only benefit USGS scientists, but will be of value to policy makers and resource managers in identifying additional needs for USGS participation in supplying science information for the Appalachian region in the future. Based upon this information and subsequent discussions in the development of the draft science opportunities document, we hope to provide some guidance for investment of USGS resources for the future. It is hoped that all who have an interest in USGS science will use these proceedings and the draft science opportunities document to help identify issues and gaps in information that they would like the USGS to provide. Input is not only solicited, but essential, along with participation at a second workshop planned for the spring of 2002. This workshop will invite existing and potential USGS partners to participate and provide input to the final science opportunities document that will be published and possibly used as a guide for future USGS research and data collection in the Appalachian region.

D. Briane Adams

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The Southern Appalachians: A Changing World

Sandra Clark[1], Judith Back[1], Anne Tubiolo[2], and Elizabeth Romanaux[3]
[1]U.S. Geological Survey, 954 National Center, Reston, VA 20192
[2]National Park Service, Harpers Ferry Center/AV Arts, Fillmore Street, Harpers Ferry, WV 25425
[3]Liberty Science Center, Liberty State Park, Jersey City, NJ 08305

The Southern Appalachians is a region known for its beauty and rich biodiversity. Although it includes some of the most visited recreation areas in the country, few are aware of the geologic underpinnings that have contributed to the beauty, ecosystems, and quality of human life in the region.

The U.S. Geological Survey, in cooperation with the National Park Service, produced a 25-minute video to explain how geologic processes over the last billion years have interacted with other elements in the environment to result in the region we see today. The video includes several animated segments that show paleogeographic reconstructions of the Earth and movements of the North American continent over time; the formation of the Ocoee sedimentary basin beginning about 750 million years ago; the collision of the North American and African continents about 270 million years ago; the formation of granites and similar rocks, faults, and geologic windows; and the extent of glaciation in North America. The animated segments are tied to familiar public-access sites in the region. They illustrate geologic processes and time periods, making the geologic setting of the region more understandable to tourists and local students. The video reinforces the concept that understanding geologic processes, rates, and setting is an important component of informed land management to sustain the quality of life in a region.

The U.S. Geological Survey sought feedback for the concept of the video from the Southern Appalachian Man and Biosphere (SAMAB) Program and its member agencies before starting work on the video. Suggestions by SAMAB's Environmental Education Committee significantly strengthened the resulting product. U.S. Geological Survey will continue to work with SAMAB to distribute the video to middle and high schools and Visitors Centers in the region.

A Framework for Integrated Science in the Appalachian Mountain Range

John D. Peine
USGS-Leetown Science Center
Southern Appalachian Field Laboratory
University of Tennessee at Knoxville

ABSTRACT

There is considerable scientific advantage to examining the Appalachian mountain range from a holistic perspective. First and foremost is that the mountains represent a continuous transect roughly following the configuration of the east coast of the U.S. This paper provides a synopsis of the distinctions of the region, over arching stressors and key responses within an environmental and socio-economic context, and opportunities for integrated science. The opportunity to structure a USGS science program at this geographic scale will allow for collaboration among scientists focusing on similar issues at various locations up and down the mountain range. There will also be a greater opportunity to engage in interdisciplinary science targeted to multidimensional issues. Climate sensitivity and change is a key overarching issue as is air and water pollution and changing land use, all of which is connected to the ever growing list of pests, pathogens and invasive species. Urbanization, mining and forest practices, and recreation are inextricably linked to sustainability in a social, cultural, economic and environmental context. Through the proposed initiative, the USGS can demonstrate its leadership and relevance to the conduct and management of integrated science. Also, as goals of the emerging USGS Science Impact and INCLUDE programs, the initiative provides an opportunity to demonstrate how to most effectively distribute scientific information in a useful form and context into the hands of decision-makers working toward improving and sustaining quality of life throughout the Appalachian Mountain region.

DISTINCTIONS OF THE BIOGEOGRAPHIC REGION

Geographic and Institutional Context

The Appalachian region includes the entire state of West Virginia and parts of 12 other states. For the purposes of this paper, comments will be directed to the highlands portion of the region. The Appalachian Mountains were formed when "continental drift" caused western Africa to collide with North America during the end of the Paleozoic era, about 230 million years ago. At that time, all the Earth's major continents had merged to form the single super continent called "Pangaea". Much of the genera of vascular plants prevalent then remain in the Appalachians and in the mountains of eastern China.

The Appalachian Mountains are rich in institutions dedicated to resources management, economic development and social services. The Southern Appalachian Man And Biosphere Cooperative (SAMAB) is an example of a consortium of public agencies working together for ecosystem management and sustainable development. Members include the Appalachian Regional Commission, Tennessee Valley Authority, Economic Development Administration and various federal agencies associated with science and/or management of natural resources (Hinote, 1999). The most notable accomplishment of SAMAB was to conduct a regional assessment of environmental, economic and social conditions, the results of which were published in 1996 (Berish and others, 1999). From that effort, the Southern Appalachian Regional Information System has evolved and is now incorporated in the Southern Appalachian Node of the National Biological Information Infrastructure (SARIS, 2001; SAIN, 2001).

Key factors contributing to the strength of the region being a focus for USGS integrated science include the following (Randolph and others, 1999):

- Diversity and abundance of natural and cultural resources residing within the complex topography;
- The degree to which the native environment is intact and/or in recovery;
- The size and configuration of protected lands being managed within the principles of sustainability;
- The presence of regional interagency organizations dedicated to integrated ecosystem management, information management and environmental education;
- The presence of robust programs to inventory, monitor, assess and research the natural resources and human dimensions of the region;
- The variety and severity of threats to natural resources occurring at the species, community and ecosystem levels; and
- The abundance of creative management and education actions being pursued to mitigate perturbations.

Continental Transect

The 2,168 mile-long Appalachian Trail from Maine to Georgia provides a reference for the linear transect afforded by the Appalachian Mountain range. This transect provides a geographic reference point to compare similar scientific investigation conducted at various latitudes and/or topographic positions along the mountain range. Examples include studies of black bear populations, brook trout, migratory birds, salamanders, spruce-fir forests and air pollution. This linear transect is in some instances a time capsule as well, particularly in the context of evaluating the environmental effects of various stressors. For example, many invasive pests and pathogens, such as dogwood anthracnose, gypsy moth and Hemlock adelgid, first invaded the northeast and in some cases have yet to reach the southeastern terminus of the mountain range (Schlarbaum and others, 1999). SAMAB is sponsoring a citizen-science program for resource monitoring along the Appalachian Trail.

Biological Diversity

The Appalachian Mountain range provided a geographic refuge for biodiversity and species richness during a series of ice ages. The spruce-fir forest in the southern Appalachians is a highly threatened remnant ecosystem of the last ice age. At the turn of the 20th century, mixed mesophytic and oak-chestnut forests once dominated throughout most of the region. Hemlock-white pine-northern hardwoods dominate in the north, and oak-pine in the south (Brawn, 1950). As an international biosphere reserve, the southern Appalachians are globally renowned for the biodiversity of their temperate forests and freshwater mountain rivers and streams. The Southern Appalachian Assessment (SAA, 1996) identified 16 broad vegetation classes and 31 rare community types such as the high elevation balds. The Nature Conservancy recognizes 200 community types in the region (P. White, pers. commun.). In the southern Appalachians alone, there are 2,250 species of vascular plants, 80 species of amphibians and reptiles, 175 species of birds and 65 species of mammals (Randolph and others, 1999). A larger percentage of species of nesting song birds are neotropical migrants (75 species) than anywhere else in the nation. The largest and most striking group includes 50 species of wood warblers (Simons and others, 1999). A comprehensive biological inventory is currently underway in Great Smoky Mountains National Park (ATBI, 2001). A Southern Appalachian Node has been recently established for the USGS National Biological Information Infrastructure program which among other things, will feature innovative means to access scientific information from many disciplines (SAIN, 2001). The Center for Virtual Appalachian (CVA, 2001) has identified 113 web sites on natural resources in the region. Commonly used keystone indicator species of ecological health include fresh water muscles and brook trout for the rivers and streams respectively, black bears and wood thrush for temperate forests, red spruce trees for high elevation forests and tulip popular and varieties of milkweed for ozone pollution.

Cultural Distinctions

The Native American population in the southern Appalachians was about one million when the first Europeans arrived. By the time large numbers of white settlers appeared in the southern Appalachians in the mid-18th century, the Mississippian Indian culture had been replaced by the Cherokee. Early European settlers in the southern Appalachian region were generally of three ethnic origins: Scotch-Irish, English and German. The early settlers shared many common characteristics, which are important in understanding their way of life. Many of these traits still endure in modern day residents of the region who trace their ancestry back to the early settlers. These people are proud of their cultural heritage and how they have overcome the many obstacles to their survival. Religion is an integral part of their lives and most are strongly individualistic and self-reliant. Being conservative, they tend to move cautiously toward change and are sensitive to "outsiders". Well into the 20th century, life for residents was largely tied to the land and natural resources. Perhaps more than other rural areas, physiography shaped social and culture patterns in the mountains. Each community occupies a distinct cove, hollow or valley separated from its neighbors. Land ownership patterns usually terminate at ridgetops, reinforcing the community's identity and independence (Randolph and others, 1999). These cultural dynamics are of critical importance when conveying scientific information in a community context. Today, the region, as defined by the Appalachian Regional Commission, includes 406 counties in which 20 million people reside, 42% of which live in rural areas compared to 20% nationally.

Social-Economic Challenges

The family farm was the preindustrial Appalachian regional economy. Each mountain homestead functioned as a nearly self-contained economic unit. After 1900, extractive industries such as logging and coal mining competed with mountain farmers for the use of the woodland. During the first three decades of the 20th century, private companies acquired large tracts of mountain land. Entire valleys were given over to railroads, coal mines and coal towns, while forest slopes were denuded to provide timber for underground mines and coal towns. By 1930, only 60% of the land in Appalachia was still owned by farm families (Eller, 1978). As mountain families abandoned the farms during the depression and after World War II, coal companies expanded their land ownership and introduced strip mining. Companies found that bulldozers and power shovels could remove overburden covering coal seams at a fraction of the cost of underground mining. The process stripped away soils and vegetation leaving barren slopes (Caudill, 1963). The process has been revived today to retrieve smaller coal veins by what is called mountain top removal, shoving the overburden down into ravines and covering first and second order streams.

Some of the abandoned farmland was converted into federal forests. The Clarke-McNary Act of 1924 permitted the federal government to acquire "cut over" lands for timber management purposes. The concept of creating national forests in the southern Appalachians was first documented in a report to President Theodore Roosevelt by the Department of Agriculture in 1901 (Message, 1902).

The central and southern Appalachian Mountains have long been recognized as pockets of entrenched poverty with substandard public services and devoid of viable economic opportunities. The central Appalachian region of eastern Kentucky and western West Virginia has historically been the nation's largest geographic area of poverty. There continues to be numerous Appalachian counties where the majority of the population achieves no more than an 8th grade education (US Census, 2001).

More recently, tourism has become one of the largest growth industries throughout the Appalachian region, but it does have significant limitations in that most jobs are seasonal and low paying without benefits such as health care (Tooman, 1997).

Public Land Holdings

There is a sizable public-lands estate in the Appalachian Mountains. There is a greater assemblage of federal lands here than anywhere west of the Rocky Mountains. The USFS is by far the largest federal landholder with 13 national forests totaling over 6,636,000 acres. The 25 NPS units total over 1,000,000 acres.

The primary units include Great Smoky Mountains, Shenandoah and Big South Fork. The 469 mile-long Blue Ridge Parkway links the Smokies and Shenandoah units. There are 3 national battlefields and 5 national historic areas as well.

STRESSORS AND RESPONSES

Climate Change

Climate is the most important factor influencing the relationship between soil, vegetation and site properties such as primary productivity. Climate, as a source of energy and moisture, acts as the primary control of ecosystems (Bailey, 1990). Variability in climate regimen and more extreme weather events are predictions of climate change (IPCC, 1992). Regional changes in temperature will effect local rainfall, snowfall and soil moisture conditions (Mitchel, 1990). As a result, there is also predicted to be change in the range of annual and seasonal temperatures, variability in frost free days, alterations in the quantity and timing of precipitation, and temporal distribution of moisture accumulation seasonally which in turn would vary traditional patterns in soil moisture (IPCC, 1992). Abrupt change of established climate conditions often creates stress on ecosystems (Overpeck and others, 1990). The implications of these predicted trends are exacerbated in a mountain environment.

Superimposed on the potential effects of climate change are a series of events which could be triggered by climate change such as increased incidents of pests and pathogens, fire frequency and intensity, and expanded periods of stagnant air resulting in the build up of pollution. The biological response to this litany of stressors could include decline in forest productivity; shifts in the structure and/or function of plant and animal communities; changes in population distribution; and an overall reduction in biodiversity and nutrient availability (Peine and Berish, 1999).

Examples of climate sensitivity include high elevation endemic species, organisms living in springs and first order streams, and species requiring moisture dependent habitats such as amphibians. The high-elevation spruce-fir forest ecosystem in the southern Appalachians is anticipated to be lost due to predicted climate change (Delcourt and Delcourt, 2000).

In addition, the predicted increase in frequency and ferocity of weather events represents considerable risk to people and their infrastructure. For example, in Great Smoky Mountains National Park, the snow blizzard of the century in 1994 and flood of the century in 1995 resulted in over $10 million in damages to the park infrastructure (Peine and Berish, 1999). In late spring of 1997, there was a major landslide closing Interstate-40 for several months, the primary east-west transportation artery through the southern Appalachians. This landslide followed an extremely wet spring season in the southern Appalachians.

Land Use

Land use is a key issue concerning the integrity of critical habitats and ecosystem processes. Fragmentation of habitat, and sediment runoff from disturbed lands are dominant issues within watersheds throughout the Appalachian Mountains. Land use changed dramatically with the influx of European Americans on the Appalachian landscape. Deforestation and strip mining were at their peak in the first half of the 20th century. Since that time, there has been extensive reforestation of the landscape. In recent years, strip mining has converted to mountain top removal as a means to cost effectively mine smaller coal deposits. Overburden is pushed into gullies covering first and second order streams. Chip mills have moved in to harvest via clear-cut vast tracts of privately held forestlands. Since 1985, there are 156 chip mills in the southeastern U.S. consuming an estimated 1.2 million acres of forestlands per year. Seventy percent of the pulp production in the U.S. occurs in the southeast (Shaw, 2000). Severe flooding in southwestern West Virginia on August 4, 2001 has been blamed in part on forest harvest practices and mining by mountain top removal. In addition, the Appalachians have become a preferred landscape for residential development, particularly for tourists and retirees. The urbanization of the landscape is escalating dramatically, particularly in centers of tourism and along the fringes of metropolitan regions. Lands adjacent to protected areas are particularly popular for residential and commercial development. A variety of adverse impacts on protected areas can occur from adjacent lands such as attracting wildlife to human food sources, wildlife predation by domestic animals, and noise and light pollution. In addition, there is a greater likelihood of invasion by pests such as Gypsy Moth and alien plant species, and increased access for illegal activities such as poaching native plants and animals. These problems are of greatest concern in gateway communities to national parks. Another concern is the overuse of public lands for recreation. The Southern Appalachian Assessment identified numerous recreation sites where use was reaching or exceeding carrying capacity on peak-use weekend days. The highest density of these hot spots follow the outer edge of the southern portion of the Blue Ridge Province (SAA, 1996).

Air Quality

Deposition rates for air pollution in the high elevation forests are some of the highest in the nation. The deposition comes in the form of aerosols, gases, cloud moisture and rainfall. The Appalachians has for over three decades been a focus of monitoring of air quality and air pollution effects research. Landmark research in the 1980's by scientists at Oak ridge National Laboratory documented that the highest rates of air pollution deposition in the nation occurs in the Appalachian Mountains (Johnson and Lindberg, 1992). Very high levels of ozone occur routinely in the Appalachian Mountains. In Great Smoky Mountains National Park, 90 plant species of plants have been reported to exhibit ozone foliar injury symptoms (Barish and others, 1999). The National Park Service routinely alerts park visitors of health warnings from excessive levels of ozone. This is of particular concern to through hikers on the Appalachian Trail. Also in the Smokies, extremely high correlation has been found between the level of sulfur dioxide gaseous emissions and an increase in haziness (Malm and Pitchford, 1994). Sulfur dioxide emissions have increased by a factor of five while the visual range has been reduced to one fourth of what was determined to be natural levels (Sisler and others, 1993). The Southern Appalachian Mountain Initiative program is just now completing a 7 year regional assessment of cause and effects of air pollution (SAMI, 2001). Throughout the Appalachian Mountains, the primary source of sulfate and nitrate pollution is fossil fuel power plants located in the Ohio and Tennessee River Valleys. Long range transport, deposition and effects models now available greatly enhance the potential to integrate air pollution effects into watershed assessments.

Pests and Pathogens

Exotic pests can be devastating as there is often no natural resistance present in the host species since the co-evolution of pests and their hosts have not occurred. Destruction of the American chestnut by the introduced chestnut blight fungus is the primary example in the Appalachian Mountains (Burnham and others, 1986). Transportation corridors and forest disturbance provides an opportunity for exotic pests and plants to become established, although many exotic plants do not require disturbance. These species are frequently more aggressive in occupying disturbed areas than native species (Shlarbaum and others, 1999). Examples of these plant pests include tree-of-heaven, privit, kudzu, musk thistle and Japanese grass. The end result of their invasion is the loss of some populations of native species. The exotic mammal of most concern is the European Wild Boar (Peine and Lancia, 1999). Particularly troublesome insect pests and pathogens include the Balsam and Hemlock Adelgids, Dogwood Anthracnose, Butternut Cancer, Gypsy Moth and Beech Bark disease complex. Once established, exotic pests and pathogens can be difficult, if not impossible to control or eradicate.

Community Sustainability

Cultural fabric in the Appalachian region is manifest largely in rural communities. People living in these small communities are less likely than their urban dwelling counterparts to have high quality social services such as schools and health care and fewer opportunities to find full time employment at a reasonable salary with benefits such as health care and retirement. One of the primary missions of the Appalachian Regional Commission is to aid these rural communities to achieve viable economies and public services. This has been a constant challenge over the 35-year history of the agency with mixed results. Poverty remains intransigent for countless numbers of these isolated communities. Jean Richardson, in her book *Partnerships in Communities: Reweaving the Fabric of Rural America* (2000), discusses integrating research into community action. She contends that there is no simple recipe for rural prosperity. "It is not a question of having inadequate data: as a nation we seem to flourish on data and the collection of data. The data used, whether national, regional or local, may be accurate, but what is typically missing is the integration of research with proposed actions, including actions proposed by the community itself." She mentions that applying GIS technology to convey information must be accomplished in such a way so as to foster non-technically oriented citizens to explore data fields to find information relevant to their issues of concern within an appropriate spatial and temporal context. She defines key principles of sustainable rural communities to include empowering community members, recruiting leaders particularly among women, engaging the young, encouraging innovation and fostering links to urban areas.

OPPORTUNITY FOR INTEGRATED SCIENCE

A compelling case for applying integrated science to address community sustainability issues can be made via Gatlinburg, Tennessee, the primary gateway community to the nation's most visited national park. The view of Mt LeConte is frequently obscured due to air pollution. Views of the mountains add over $30 per square foot to the value or residential real estate (Leedy, 2001). There is considerable controversy concerning road- building projects along the park boundary. One project in the community was recently stopped because of various concerns related to the park. The community, situated in a narrow valley at the foot of the steepest watershed in the Appalachian Mountain Range, is highly susceptible to flash flooding. During peak tourist seasons, there is a dense population of tourists and routine traffic congestion centered within the flash flood zone. The West Prong of the Little Pigeon River running through the heart of town has been frequently cited by the state for noncompliance of water quality standards due to fecal coliform contamination. Sport fishing in town is supported by a community operated fish hatchery where exotic rainbow trout are raised and released. There is considerable light pollution from the community intruding into the park's night sky. Black bears whose home range is centered in the national park have habitually ranged into town to partake of human-source food found in dumpsters and garbage cans. Tourists in condominiums and rental cabins routinely throw food to these bears. Local hunters come into town to hunt these easy to find bears during the height of the fall tourist season. In1997, after years of a build up of the bear population, there was a fall mast crop failure due to a late spring frost resulting in a large number of bears ranging outside the park foraging for food. Hunters were shooting bears in front of tourists, once while the bears were in a downtown dumpster. Local police were defending the rights of the hunters. National news media covered the story. Finally, under political pressure, the community recently adopted an ordinance requiring the use of bear-proof dumpsters and garbage cans, a policy state and federal wildlife officials had been advocating for 25 years previously to no avail (Newton, 1999; Peine, 2001).

Human Risks Due to Urbanization, Land Use and Climate Change

As the human population dramatically rises in the Appalachian Mountains, so do the hazards related to climate change. As noted previously, storm events are predicted to become more frequent, more extreme and less predictable as to the timing and location of their occurrence. This concern is particularly timely with the controversy in West Virginia concerning the increased potential for flooding due to mountain top removal and forest harvest practices.

In addition, the urbanization of the mountain landscape will result in more development occurring in areas of high risk from building more steeply inclined roads to building in areas susceptible to land slides and flash flooding. During periods of extended drought, urbanization encroaching on forested areas poses a danger from wild fires. An assessment of risks to people and their fiscal infrastructure would be invaluable for planning for future growth and related infrastructure development by federal, state and local government agencies. This project would provide an excellent opportunity to partner with FEMA and the ARC to demonstrate application of the emerging USGS Science Impact and INCLUDE programs.

Water Quantity, Quality and Distribution Implications from Stressors

The headwaters of countless rivers and streams are situated in the Appalachian Mountains. These water resources are vital to communities and economic interests within the related watersheds in the 12-state region. There are numerous stressors on these resources. For instance, some of the cleanest rivers in the state of Tennessee are located in Great Smoky Mountains National Park and have been designated "Outstanding Natural Resource Waters" by the state. For various reasons, the water quality standards for the designated use for three out of four of these rivers are violated within .1 to 10 miles outside the park boundary. Aquatic habitats associated with these rivers are highly impacted from runoff from impervious surfaces, sedimentation and loss of riparian habitat. Abrams Creek, the fourth designated waterway is in compliance with use standards in a rural area but only runs for 7 miles beyond the park boundary until it empties into a TVA reservoir.

As land use change in the Appalachians occurs due to mining, logging and development, and the demands for these water resources escalate by industry and urban sprawl, rivers quickly become degraded and/or over utilized. By primarily utilizing readily available data sources, there is an opportunity for USGS to partner with EPA, USFWS and state agencies to apply integrative science to selectively evaluate the long-term implications from these trends on the most critical of these water resources and related watersheds in the Appalachian region.

Threats to Ecological Integrity from Stressors

There is a need for the application of integrated science to evaluate the cumulative effect of various stressors on ecosystem viability for priority ecosystems and federal lands managed for natural resource sustainability. Examples of opportunities for integrated ecological science include the following:

- Risk assessment of the highly threatened spruce-fir ecosystem in the southern Appalachians is a concern of the NPS and USFS. This ecosystem includes a disproportionate number of endemic species. Threats from climate change, air pollution and numerous insect pests and pathogens are primary stressors (Nicholas and others, 1999).
- Fragmentation of forest landscapes reduces the potential to maintain corridors linking federal and state protected areas, a high priority issue of concern to EPA Region IV. They are developing a Web based data system called GeoBook whose primary goal is to facilitate identification of greenways to link key habitats and protected areas. Black bears and wood thrush are good indicator species for this type of analysis (Clark and Pelton, 1999; Simons and others, 1999).
- Adverse effects from changing land use on adjacent lands are particularly a concern to NPS officials in Shenandoah and Great Smoky Mountains National Parks, the Blue Ridge Parkway, the Appalachian Trail and selected national civil war battlefields. Along with threats to the integrity of the ecosystem, aesthetic values such as viewsheds are of concern as well.
- Mining has been a prominent activity for over 75 years, in central Appalachia. Acid mine drainage, loss of first and second order streams, unstable land fills and loss of native vegetation are all critical concerns.
- Threats to habitat of sensitive, threatened and endangered species are a concern of the USFS and USFWS throughout the region.

- Fire ecology is not well understood throughout the region and deserves more attention as NPS and USFS land managers increase their prescribed burn activities (Buckner, pers. commun. , Buckner and Turrill, 1999).

Appalachian Community Sustainability Assessments

As described previously in the Gatlinburg case example, there is considerable value in providing science-based information to communities in Appalachia applicable to problem solving and proactive planning for a sustainable future. Most federal agencies have numerous Web based national information centers including EPA, US Census, USGS, NRCS, USFWS, NPS, USFS, TVA and many others. Several organizations are dedicated to providing information on the people, economy and the environment in the Appalachian region. The primary agency covering the entire region is the ARC. The Center for Virtual Appalachia is another institution similarly dedicated (CVA, 2001). The Southern Appalachian Node of the USGS-NBII program is just beginning to establish a regional information system. The most advanced regional organization of its type is the Virginia based Canaan Valley Institute dedicated to providing technical information at a community level (CVI, 2001). This group has considerable experience in designing GIS based programs to access spatial databases on the Internet that are particularly user friendly. They also train individuals how to access and apply the information to community-based issues. Scientists engaged in integrated science in the Appalachian Mountains should be encouraged to focus their research on specific community-based client needs as well as involving, from the beginning of the project, organizations specializing in information transfer to the target clients. Project budgets should reflect this intent by allocating resources as needed to focus on client access to and utilization of the scientific information produced. Analysis of the utility of the scientific information produced for the client should be included as an objective in every project as well. This is what the new USGS Science Impact program is all about.

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Overview of Current and Future Fossil Energy Geoscience in the Eastern Region

Ione L. Taylor and Senior Scientists of Eastern Energy Resources Team
U.S. Geological Survey, MS-956, National Center, Reston, VA 20192

The Eastern Energy Resources Team conducts research within the context of the USGS Energy Resources Program. Scientists on the team have a long history of both fossil fuel resource assessment and coal, oil, and gas science in the Appalachian Basin. Areas of research range from resource analysis (genesis, distribution, quantity, and quality) to the environmental and health impacts of fossil fuel extraction and use. Work in the Appalachian Basin is currently focussed on four major projects: (1) oil and gas assessment (Milici et. al, this volume), (2) coal assessment (Ruppert et. al, this volume), (3) environmental impacts of coal extraction (Cecil et. al, this volume); and (4) geologic framework of energy resources (Ruppert et. al, this volume).

The first two projects will be completed in fiscal year 2002. The principal products will be GIS-based resource assessments of coal, oil, and gas – including both conventional gas, as well as unconventional gas, such as coal bed methane and basin-centered gas. The coal assessment will include, in addition to the geoscience-based assessment, the incorporation of modeled mining costs for an economic analysis of two top-producing Appalachian coal beds. The Coal Extraction Environmental Project is designed to examine the three major energy-related impacts of coal mining: mountain top mining and valley fill, mine pool coalescence and prediction, and mitigation and remediation of contaminated mine drainage. Research on mine drainage includes acidity of mine-related waters and potentially toxic metals (e.g. iron-bearing flocculates and manganese-bearing aqueous species). This project provides an excellent opportunity for collaboration with the water and biologic disciplines.

The forth project, Framework Geology and Energy Resources in the Central Appalachian Basin, is currently in an early stage. It is designed to utilize data, products and expertise coming out of the assessment projects. It represents a foray into a new type of product. In addition to the coal resources data, the project will also incorporate extensive USGS data on coal chemistry in the Appalachian Basin, including ash yield and moisture content, sulfur, and selected trace elements such as arsenic and mercury. The quantity, distribution and quality of all the fossil fuels in the Appalachian Basin will be consolidated within a GIS using the geologic and basin thermal history as the conceptual framework. This will be a first attempt to develop a true "energy mix" product. Our intention is for decision-makers at many levels to use this product to make informed choices about energy options within a region or within a given market. The goal is to help the Nation use non-renewable energy resources more wisely on the path to sustainability. Future incorporation of hydrologic and biologic data could enhance the usefulness and breadth of this product.

The Appalachian Basin is an excellent choice for USGS's pilot area for such an energy mix product for several reasons: (1) extensive data and expertise for all fossil energy product types (commodities) exist within the basin; (2) all of the commodities (conventional and unconventional gas, coal and oil) exist in proximity within the basin; (3) areas of resource occurrence (supply) are typically adjacent to areas of resource consumption (demand); (4) electric power generation is currently predominantly from coal, which is typical of the entire US; although proposed additions to generating capacity are anticipated to be fueled by natural gas; (5) the basin contains the entire history of land use for this country and thus encompasses most of the infrastructure issues associated with energy extraction and use. Infrastructure includes aging pipelines and other aspects of transportation, aging power plants, and abandoned mine lands, as well as competing land use issues of urban/suburban growth versus resource (minerals and energy) extraction and utilization.

Land Surface Change and Analysis

Dave Kirtland
U.S. Geological Survey, Eastern Region Geography, 521 National Center, Reston, VA 20192

The impact of land use and land cover change on the environment is substantial. Both represent a complex interaction of human and natural forces. The need to understand this interaction has been recognized as a critical challenge for environmental science and is a pillar of several scientific programs such as the U.S. Global Change Research Program. To help address this need, the National Mapping Discipline is investigating trends in contemporary U.S. land cover change during the late 20th century. A pilot phase of the project has been completed and work has begun on measuring the sectoral, spatial, and temporal variability of land use and land cover change for five time periods in 84 conterminous U.S. ecoregions. Documenting the rates and patterns of change across the nation and determining what sectors and time periods are most dynamic provides the context for investigating the driving forces and consequences of change. Preliminary work in the north central region of the Appalachians indicates that change from one land cover type to another during the period 1973 to 1992 has been minimal, but cyclical change such as forest to grassland to forest has occurred.

The Collaborative Environmental Monitoring and Research Initiative in the Northern Appalachian Region

Peter Murdoch[1], Richard Birdsey[2], and Ken Stolte[2]
1 U.S. Geological Survey, 425 Jordan Rd., Troy, NY, 12180
2 U.S. Forest Service, 11 Campus Blvd., Suite 200, Newtown Square, PA, 19073

The past 20 years of environmental research have shown that our world is not made up of discrete components acting independently, but rather of a mosaic of complex relationships among air, land, water, living resources, and human activities. Several resource management agencies have adopted a policy of "Ecosystem Management" for their lands and waters, but seldom have multi-component, ecosystem-level information to work with. Unfortunately, there is more to creating a scientifically-rigorous collaboration among programs than just deciding to work in the same region or make our data available to each other. Much of the information currently being collected is fragmentary and incompatible because it is collected through programs that are designed and conducted at different scales or for different objectives, and because protocols are inconsistent in sampling methodology and data management. The Delaware River Basin Collaborative Environmental Monitoring and Research Initiative (CEMRI) links existing intensive ecological research and monitoring stations, regional surveys, fixed-site monitoring networks and remote sensing programs, in order to track complex environmental issues at a range of spatial and temporal scales. The enhanced sampling is designed to allow integration of extensive monitoring with process-level studies, and facilitate scaling from intensive research sites to extended regions. At each sampling tier, measurement protocols have been enhanced to address several important regional issues: (1) causes, consequences, and regional extent of calcium depletion in the forests of the Appalachian Plateau, (2) forest biomass and productivity in the Delaware River Basin, (3) protocols for identification and monitoring of forests vulnerable to non-native invasive pests, (4) forest fragmentation and associated ecosystem changes, and (5) integration of forest and water monitoring to evaluate the effects of forest cover changes on water quality of the Delaware River. Programs participating to date include USFS Forest Health Monitoring, Forest Inventory and Analysis, and Global Change Research Programs; USGS National Water Quality Assessment Program, District COOP program, the National Mapping Division's National Hydrologic Dataset program, and the National Atmospheric Deposition Program/National Trends Network; and National Park Service inventory and monitoring programs. The Initiative is serving as a model for regional collaborative research and monitoring networks that could be deployed throughout the United States.

SESSION II

Application of Coal Geology to Prediction, Prevention, Mitigation and Remediation of Contaminated Mine Drainage from Coal Mining in the Appalachian Basin
C. Blaine Cecil, Susan Tewalt, Frank Dulong, and Sandra Neuzil

Current Issues in Appalachian Coal Hydrology and Related Disciplines
Hugh E. Bevans

Water-Quality Trends for a Stream Draining the Southern Anthracite Field, Pennsylvania
C.A. Cravotta, III and M.D. Bilger

Effects of Acidic Runoff Episodes on Fish Communities in Appalachian Streams of Pennsylvania
Robert F. Carline, William E. Sharpe, and David R. DeWalle

Metal Contamination and Acid Drainage Associated with Abandoned Metal and Sulfur Mines in the Appalachian Region
Robert R. Seal, II and Jane M. Hammarstrom

Tracking the Effects of Acidic Deposition in Medium-Scale Forested Watersheds of the Eastern United States
Peter S. Murdoch, James B. Shanley, and Thomas Huntington

Patterns of Imperilment of Southern Appalachian Fishes
Noel M. Burkhead, Stephen J. Walsh, and Robert M. Dorazio

Framework Geology and Energy Resources in the Central Appalachian Basin
Leslie F. Ruppert, Robert T. Ryder, Robert C. Milici, John E. Repetski, Linda J. Bragg, Susan J. Tewalt, Michael H. Trippi, Elizabeth L. Rowan, and Robert E. Crangle

Application of Coal Geology to Prediction, Prevention, Mitigation and Remediation of Contaminated Mine Drainage from Coal Mining in the Appalachian Basin

C. Blaine Cecil, Susan Tewalt, Frank Dulong, and Sandra Neuzil
U.S. Geological Survey, MS-956, National Center, Reston VA 20192

Coal from the Appalachian region has been a major source of energy to the nation for over two hundred years. Appalachian basin coal fueled America through a civil war and has helped win two world wars. In addition Appalachian coal has served as the basis for the steel, auto, organic chemicals, chlorine, and aluminum industries while keeping America warm in the winter and cool in the summer. Coal currently serves, and will continue to serve, as the primary fuel for the generation of the Nation's electricity. The benefits of coal utilization, however, have not come without costs. Coal extraction and utilization have had significant environmental impacts. Historically, coal extraction has lead to prodigious problems in contaminated mine drainage (CMD) subsequent to mine closure and abandonment. Contaminated drainage has been, and continues to be, particularly acute in streams in Pennsylvania, Ohio, West Virginia, and Maryland. Such drainage has had far ranging impacts on water quality as well as fish and wildlife. The impact of mine drainage from future mine closures is largely unknown, but such impact may cause extensive degradation of rivers in the region.

There are numerous other problems associated with coal mining and utilization. In recent years there have been major problems with failure of settling ponds associated with coal preparation operations. Coal-based synthetic fuels operations contaminate streams in the Appalachian region on occasion. Mine subsidence has damaged homes and other surface structures, and disrupted domestic water supplies. Many people are concerned about the impact of surface mining practices known as "mountain top mining" in the low-sulfur coal fields of southern West Virginia. Currently there is legislation pending in Congress for "clean coal technology". If successful, this legislation will likely lead to reactivation of mining in the high-sulfur coal regions in Pennsylvania, Ohio, West Virginia, and Maryland where CMD has been most acute in the past. The impact of future mining and waste disposal from clean coal technology processes on water quality in the Ohio River basin and drainage to the Chesapeake Bay is largely unknown. Power plants produce huge quantities of fly ash that are currently disposed of in slurry ponds. Little is known about the impact of slurry-pond drainage on surface water quality. Ideally, all of these issues, and perhaps others, need to be identified, clarified, and addressed through sound science in support of maximizing energy production while minimizing environmental impacts.

As coal continues to supply a significant part of the Nation's energy demands, USGS research can identify and clarify past, current, and future problems that may be associated with coal mining, cleaning, and utilization in the Appalachian region. The issues will require prioritization and recommendations to develop scientific research that will 1) predict and prevent future problems 2) mitigate problems that could arise from closure of active mines, and 3) remediate problems associated with abandoned mines. Coal geology has direct application to all aspects of coal mining issues. Comprehensive science planning can be accomplished through discussions with scientists from the USGS, other Federal, State, and local agencies, Universities, and the private sector.

Current Issues in Appalachian Coal Hydrology and Related Disciplines

Hugh E. Bevans
U.S. Geological Survey, Charleston, West Virginia

Modern high-extraction surface and underground coal-mining activities in Appalachia have the potential for causing regional-scale environmental disturbances. Mountaintop removal/valley fill surface coal mining typically involves blasting and excavating hundreds of feet of overburden from the tops of mountains to extract multiple coal seams. After the coal is extracted, some overburden is replaced on the former mountaintops, but large quantities of waste overburden are dumped into adjacent headwater valleys.

At long-wall coal-mining operations, continuous-mining machines enter coal seams at their outcrops and mine beneath mountainous areas. The machines support the overlying rock strata as the coal is extracted and allow the mine roof to collapse as the operation advances. The Pittsburgh Coal seam, which underlies most of the Monongahela River Basin in southwest Pennsylvania and north central West Virginia, currently is being mined by long-wall operations and historically has been mined by underground room-and-pillar operations. Active production of the seam is rapidly approaching completion. Active mines must continuously operate large pumps to dewater because production areas are far below the regional water table. As the mines close and dewatering operations cease, ground-water levels will rise and fill this extensive mined-out area with acidic water.

The onsite processing of coal is common to coal-mining operations throughout Appalachia. Process wastewater with fine coal and waste rock refuse material and associated trace elements, known as coal slurry, is stored in impoundments. Catastrophic failures of impoundments have occurred due to dam failures and collapses into underground mines.

Hydrologic and related issues from Appalachian coal-mining activities include impacts on water budgets; streamflow characteristics; surface- and ground-water quality: flood, debris-flow, and landslide hazards; subsidence and collapses; stream morphology; and aquatic habitat and ecology. Many of these coal-mining issues are cumulative and could be subjects of regional interdisciplinary studies. For instance, relations among streamflow characteristics, stream morphology, and aquatic habitat in mountaintop removal areas could be investigated. Other examples include investigations of floods, landslides, and debris flows; or relations of geochemistry, water quality, and aquatic ecology. The U.S. Geological Survey has the expertise and logistical capability to conduct these regional interdisciplinary investigations.

Water-Quality Trends for a Stream Draining the Southern Anthracite Field, Pennsylvania

C.A. Cravotta, III and M.D. Bilger
U.S. Geological Survey, 215 Limekiln Road, New Cumberland, PA 17070

EXTENDED ABSTRACT

Streamflow, chemical, and biological data for the northern part of Swatara Creek, which drains a 112-km^2 area in the Southern Anthracite Field of eastern Pennsylvania, indicate progressive improvement in water quality since 1959, after which most mines in the watershed had been flooded. Drainage from the flooded mines contributes substantially to baseflow in Swatara Creek. Beginning in 1995, a variety of treatment systems and surface reclamation were implemented at some of the abandoned mines. At Ravine, Pa., immediately downstream of the mined area, median SO_4 concentration declined from about 150 mg/L in 1959 to 75 mg/L in 1999 while pH increased from acidic to near-neutral values (medians: pH~4 before 1975; pH~6 after 1975). Fish populations rebounded from nonexistent during 1959-90 to 21 species identified in 1999. Nevertheless, recent monitoring indicates (1) episodic acidification and elevated concentrations and transport of Fe, Al, Mn, and trace metals during stormflow; (2) elevated concentrations of Fe, Mn, Co, Cu, Pb, Ni, and Zn in streambed sediments relative to unmined areas and to toxicity guidelines for aquatic invertebrates and fish; and (3) elevated concentrations of metals in fish tissue, notably Zn. The metals are ubiquitous in the fine fraction (<0.063 mm) of bed sediment in mining-affected tributaries and the main stem of Swatara Creek. Because of scour and transport of streambed deposits, concentrations of suspended solids and total metals in the water column are correlated, and those for stormflow typically exceed baseflow. Nevertheless, the metals concentrations are poorly correlated with streamflow because concentrations of suspended solids and total metals typically peak before peak stream stage. In contrast, SO_4, specific conductance, and pH are inversely correlated with streamflow because of dilution of poorly buffered stream water with weakly acidic storm runoff derived mainly from low-pH rainfall. Declines in pH to values approaching 5.0 during stormflow events or declines in redox potential during burial of sediment could result in the remobilization of metals associated with suspended solids and streambed deposits.

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Effects of Acidic Runoff Episodes on Fish Communities in Appalachian Streams of Pennsylvania

Robert F. Carline[1], William E. Sharpe[2], and David R. DeWalle[2]
[1]Pennsylvania Cooperative Fish and Wildlife Research Unit, Biological Resources Division, U.S. Geological Survey, Merkle Laboratory, University Park, PA 16802
[2]School of Forest Resources and Environmental Resources Research Institute, Pennsylvania State University, Land and Water Building, University Park, PA 16802

During the past 20 years, government and university scientists at Penn State have been conducting studies on the effects of acidic runoff episodes on fish communities in headwater streams on the Allegheny Plateau. Acidic episodes can cause pH values to decline by more than one unit, with minimum values approaching 4.5. Simultaneously, concentrations of total dissolved aluminum may exceed 400 $\mu g/L$. Streams subjected to such episodes are characterized by simple fish communities. Where episodes are severe, the brook trout (*Salvelinus fontinalis*) is the only species present.

Acidic episodes can affect all life stages of fish. Brook trout embryos incubate in stream gravel over winter and are vulnerable to acidic episodes. Slimy sculpins (*Cottus cognatus*) spawn in spring when females attach eggs to the undersides of rocks. Mature slimy sculpins fail to spawn when subjected to acidic episodes. *In situ* bioassays have been used to demonstrate that acidic episodes can cause more than 80 percent mortality of brook trout and slimy sculpins. Brook trout are displaced downstream in response to acidic episodes. Displaced trout frequently congregate in areas where alkaline groundwater seeps or tributaries enter main channels. These chemical refugia mitigate lethal effects of episodes. Population density of brook trout is strongly related to episode severity, and many populations seem to be transient because of periodic lethal conditions caused by episodes. In 1994 and 1995, 75 streams subjected to acidic episodes had lower pH, lower total alkalinity, and supported fewer fish species than they did 25 to 30 years prior. Thus, acidic episodes affect both fish productivity and fish diversity.

Since passage of the Clean Air Act Amendments in 1990, there has been an improvement in air quality with notable decreases in concentrations of sulfate and hydrogen ions in precipitation. The consequences of these air quality improvements on stream chemistry and associated biological responses need to be documented to determine if historical trends of declining water quality have been reversed or if additional emission controls are warranted.

Metal Contamination and Acid Drainage Associated with Abandoned Metal and Sulfur Mines in the Appalachian Region

Robert R. Seal, II and Jane M. Hammarstrom
U.S. Geological Survey, 954 National Center, Reston, VA 20192

ABSTRACT

Massive sulfide and gold deposits are the two most problematic metallic mineral-deposit types in the Appalachian region from an environmental perspective. The environmental impacts of abandoned mines developed from massive sulfide deposits result from the formation of metal-laden acid drainage and from the presence of fine-grained, metal-rich mine wastes. Suites of problematic metals associated with these deposits differ with the type of massive sulfide deposit; in the Appalachian region, these are generally of either Kuroko or Besshi type. Mine drainage is mostly a threat to aquatic ecosystems, but metals also can contaminate local drinking water supplies. Abandoned gold mines are of environmental concern because of the mercury used in the gold-extraction process, which poses a threat to human health due to its ability to bioaccumulate in the foodweb, especially in aquatic systems.

INTRODUCTION

The environmental geochemistry and impact of abandoned metal and sulfur mines in the Appalachian region arise from a combination of factors that include the geology of the deposits, the geology of the surrounding watersheds, and the mining and ore-processing methods used. In addition to elevated concentrations of acidity, iron, aluminum, and manganese in drainage typically associated with coal mines in the eastern United States, which are dominantly aquatic ecosystem threats, the heavy metal suite associated with abandoned metal and sulfur mines poses a variety of other threats to both aquatic ecosystems and human health. Human-health effects from abandoned metal mines typically follow inhalation or ingestion pathways. Examples of potential threats include airborne, lead-rich dusts derived from mine wastes, elevated concentrations of arsenic in ground waters around abandoned mines and unmined deposits, and bioaccumulation of mercury in fish downstream from mine sites.

Environmental issues related to abandoned metal and sulfur mines are of interest to a variety of organizations, because of their environmental impact both to ecosystems and humans, their historical significance, and current regulatory requirements. The list is headed by numerous government organizations at federal, state, and local levels. The U.S. Environmental Protection Agency (EPA) recently placed the Elizabeth copper mine in Vermont on its National Priorities (Superfund) List, and the nearby Ely copper mine has been proposed for listing. The EPA is also involved in activities in the Copper Basin, Tennessee, and is exploring possibilities in Virginia, North Carolina, and Maine. The U.S. Army Corps of Engineers has authority to address abandoned mine issues. The Corps of Engineers has been assessing the extent of metal-mine issues in the Appalachians. State agencies concerned with abandoned mine issues include departments of environmental protection, environmental conservation, and transportation, among others. Local governments are concerned about the effects of the abandoned mines on environmental quality and property values, and the effects of remediation on property values, government spending, and quality of life.

This paper focuses on the environmental effects of abandoned mines of two types of metal and (or) sulfur deposits: massive sulfide deposits, principally exploited for their base- and precious-metal, and (or) sulfur contents, and gold deposits, the latter type commonly having imported mercury to the site for ore beneficiation purposes. Massive sulfide deposits have long been recognized for their environmental impacts in the Appalachians, whereas the potential environmental impact of the gold deposits has been under-appreciated.

ECONOMIC GEOLOGY AND MINING PRACTICES

The Appalachian region has had a long history of metal and sulfur mining dating back to Pre-Revolutionary times (Feiss and Slack, 1989). Of the numerous mineral deposit types that have been mined over this period, massive sulfide deposits, historically valued for their base- and precious-metal, and sulfur contents, and gold deposits hold the greatest potential for adverse environmental impacts.

Massive sulfide deposits formed on the ancient seafloor through submarine-hydrothermal processes and can be classified into several categories on the basis of host-rock compositions and metal contents (Franklin and others, 1998; Seal and others, 2000). In the Appalachian region, Kuroko-, Besshi-, and Noranda-type massive sulfide deposits are the most common. Kuroko- and Noranda-type deposits are characterized by host-rock packages dominated by bimodal submarine volcanic rocks with subordinate amounts of marine sedimentary rocks; they form in island-arc settings. The volcanic rocks associated with Kuroko-type deposits are dominantly felsic, whereas those associated with Noranda-type deposits are dominantly basaltic. Besshi-type deposits are characterized by host-rock packages dominated by siliciclastic marine sedimentary rocks and volumetrically minor to subequal basaltic volcanic rocks and subvolcanic intrusions. They form in rifted basins along continental margins.

Massive sulfide deposits are found throughout the Appalachian orogen in Proterozoic and Paleozoic rocks from Alabama to Maine, and northeast into Maritime Canada (Fig. 1). Notable deposits in New England include the Besshi-type deposits of the Vermont copper belt, Elizabeth, Ely, and Pike Hill (Hammarstrom and others, 2001a, b; Seal and others, 2001a, b; Slack and others, 2001), the Kuroko-type deposits in coastal Maine (Feiss and Slack, 1989), and the unmined Noranda-type deposit at Bald Mountain, Maine (Seal and others, 1998a). The USGS Mineral Resources Data System lists 71 Kuroko-type mines or prospects and 73 Besshi-type mines or prospects in the Appalachian states (McFaul and others, 2000). Within the central and southern Appalachians, significant Kuroko-type deposits or mining districts include the Pyriton deposit in Alabama, the Chestatee, Jenny Stone, and Swift deposits in Georgia, and the Mineral district and Cabin Branch deposit in Virginia (Stephens and others, 1984; Neathery and Hollister, 1984; Feiss and Slack, 1989). Significant Besshi-type deposits or districts include the Stone Hill deposit in Alabama, the Villa Rica deposit in Georgia, the Copper Basin district in Tennessee, the Fontana, Hazel Creek, and Ore Knob deposits in North Carolina, and the Gossan Lead district in Virginia (Neathery and Hollister, 1984; Stephens and others, 1984).

The ore mineralogy of the Kuroko-type deposits is dominated by pyrite, chalcopyrite, and sphalerite, with lesser pyrrhotite, galena, arsenopyrite, and tetrahedrite (Franklin and others, 1981; Seal and others, 2000). Gangue minerals typically comprise quartz, feldspar, muscovite, biotite, and amphibole. Ore mineralogy of Besshi-type deposits is dominated by pyrrhotite ± pyrite, chalcopyrite, and sphalerite, with minor galena (Slack, 1993; Seal and others, 2000). The gangue mineralogy is dominated by quartz, muscovite, biotite, plagioclase, and hornblende, with minor dolomite and ankerite. However, the stratigraphic package surrounding Besshi-type deposits can contain significant amounts of calcite and dolomite (Slack, 1993; Slack and others 2001; Seal and others, 2001b). The mineralogy of Noranda-type deposits is similar to that of Kuroko-type deposits, but can have higher proportions of chalcopyrite, and pyrrhotite may constitute a major phase (Seal and others, 2000). Collectively, the ore mineralogy of these deposits represents important sources of acidity and metals to impact surrounding ground and surface waters; the gangue mineralogy also provides a source of aluminum and manganese.

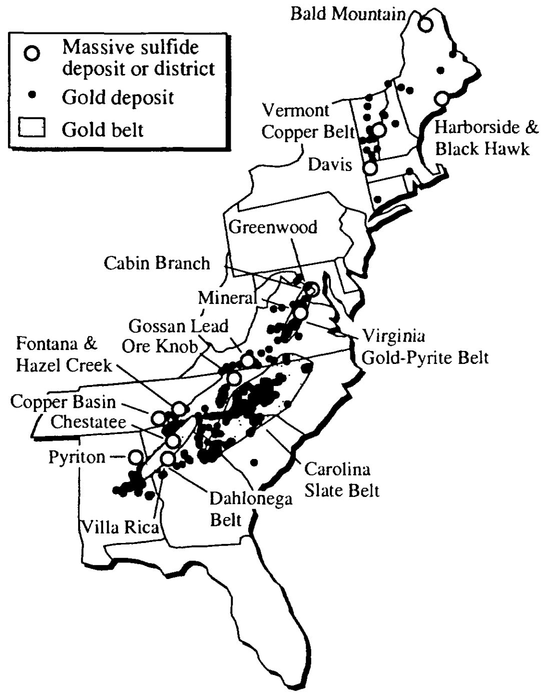

Figure 1. Map showing distribution of massive sulfide and gold deposits in the Appalachian region. Data from Feiss and Slack (19890 and McFaul and others (2000).

Massive sulfide deposits typically form lenticular or tabular bodies that range from several meters to tens of meters in thickness, and can extend laterally for hundreds to thousands of meters. They form on or beneath the sea floor. Thus, their modern geometry depends on the tectonic history of their host rocks. Because of varied geometries, massive ores are exploited by either open pit or underground methods. The ore-processing methods can vary greatly from site to site depending on the commodity or commodities sought, and the era of mining. Differences in mining and ore-processing methodologies can cause distinct differences in the character of the mine wastes, in addition to differences resulting from the natural variability of the ores (Hammarstrom and others, 2001a, b). Invariably, processing of the ores required the crushing of metalliferous rock to sizes ranging from cobbles to sand. Waste material contains high concentrations of pyrite and (or) pyrrhotite. Because of the small grain size and high sulfide content, mine wastes from massive sulfide deposits have the potential to release significant amounts of acid and metals to the surrounding environment. The wastes commonly contain limited amounts of carbonate minerals, and some lime may have been used in flotation circuits. Therefore, the mine wastes generally offer limited acid-neutralizing potential.

Gold mines in the Appalachian region exploited several types of gold deposits including low-sulfide gold-quartz vein (a.k.a. mesothermal, Mother Lode-type, shear-zone-hosted) deposits, gold-bearing massive sulfide deposits, their weathered equivalents, and placer deposits derived from these primary and secondary deposit types. Nearly 1,200 gold mines or prospects are known in the East, with the majority (96 %) occurring in Virginia, North and South Carolina, Georgia, and Alabama (Fig. 1; McFaul and others, 2000). The main historic gold districts or belts include, from north to south: (1) the Virginia gold-pyrite belt, including the Mineral district; (2) the Carolina slate belt, North and South Carolina; (3) the Dahlonega district, Georgia (and extensions into northeastern Alabama); and (4) the Hog Mountain district, Alabama (Feiss and Slack, 1989). The mineralogy of low-sulfide gold-quartz vein deposits is relatively simple; the deposits are dominated by quartz and carbonate minerals (siderite, ankerite, dolomite, magnesite, or calcite), with lesser sulfide minerals (pyrite, pyrrhotite, arsenopyrite), and gold (Ashley, in press). Other common gangue minerals, either within the veins or in adjacent wall rocks, include muscovite, chlorite, biotite, and fuchsite. Gold-bearing massive sulfide deposits share many characteristics with the massive sulfide deposits described above, the most significant examples being found in the Carolina slate belt.

Historic gold production in the central and southern Appalachians used three different methods of mining: (1) open-pit and underground mining of bed-rock ores; (2) hydraulic mining of saprolitic ores; and (3) placer mining of stream gravels. A typical progression of mining in the Dahlonega belt started with placer mining, followed by hydraulic mining of saprolitic ores (the so called "Dahlonega method"); when hydraulic mining reached bedrock, underground mining commenced (Yeates and others, 1896; Pardee and Park, 1948). Bedrock mining required the crushing of ores. Mine wastes from these operations typically contain minor amounts of pyrite, arsenopyrite, and other trace sulfide minerals. The limited acid-generating potential of these wastes is probably offset by the acid-neutralizing potential offered by carbonate minerals.

Of far greater environmental concern in these gold districts is the common usage of mercury amalgamation as a primary ore beneficiation technique (e.g., Ashley, in press). Mercury amalgamation has been used historically in all of the main districts and belts listed above. At present, documented use of mercury amalgamation has been identified at nearly 50 sites, which likely under represents the wide extent of its use, in light of the poor availability of historical records (Pardee and Park, 1948; Yeates and others, 1896; Sweet, 1980; Sweet and Trimble, 1983; Seal and others, 1998b, c). For example, historical and recent accounts of mining practices in the Dahlonega belt suggest the common usage of mercury amalgamation throughout the region, despite only 16 references of its use recorded in the literature (Yeates and others, 1896). For all three types of mining (placer, hydraulic, and bedrock), amalgamation was commonly used (Yeates and others, 1896).

PATHWAYS OF ECOSYSTEM AND HUMAN-HEALTH IMPACTS

Abandoned mines of massive sulfide and gold deposits cause detrimental environmental effects through a variety of pathways, which are best considered in terms of ecosystem or human-health impacts. For massive sulfide deposits, ecosystem threats are dominantly produced by acid-mine drainage. The oxidative weathering of pyrite (FeS_2) can generate acid-sulfate waters through the reaction:

$$FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+ \quad (1),$$

and the oxidative weathering of pyrrhotite ($Fe_{1-x}S$) can generate acid-sulfate waters through the reaction:

$$Fe_{1-x}S + (2-x/2)\ O_2 + x\ H_2O \rightarrow (1-x)\ Fe^{2+} + SO_4^{2-} + 2x\ H^+ \quad (2),$$

where x ranges from 0.000 to 0.125. Similar reactions for pyrite and pyrrhotite using ferric iron as an oxidizing agent are also important. Continued oxidation and hydrolysis of dissolved ferrous iron enhances acid production as described by the reaction:

$$Fe^{2+} + 1/4\ O_2 + 5/2\ H_2O \rightarrow Fe(OH)_3 + 2\ H^+ \quad (3).$$

The lower pH values generated by the oxidation of pyrite and (or) pyrrhotite enhances the ability of the drainage to carry base metals such as Cu, Zn, Cd, Co, Ni, and Pb, and to attack silicate gangue minerals, thus liberating aluminum and manganese. Once liberated, the metals and acidity can impact downstream aquatic ecosystems. The toxicity of the divalent base-metal cations on aquatic ecosystems is strongly dependent on the hardness of the water; higher concentrations of metals are needed to exceed toxicity limits at higher hardness values (Smith and Huyck, 1999).

The impact and toxicity of metals extend beyond base-flow and peak-flow conditions. Secondary metal-sulfate salts commonly form on sulfide mine wastes during dry periods; such salts provide a means of storing acidity and metals (Hammarstrom and others, 2001b). These salts readily dissolve during rain events, releasing spikes of acidity and metals that can pass through watersheds in less than 24 hours, with extreme consequences. Another deleterious effect of acid-mine drainage is found in the abundant precipitation of secondary hydrated ferric oxides, such as ferrihydrite, which coat and fill interstices in stream gravels. The precipitates destroy habitat for aquatic invertebrates, thereby eliminating the lower levels of the food chain, regardless of overall water quality.

Human-health impacts of massive sulfide deposits are generally associated with either the contamination of drinking water or the ingestion of metals on dust and other particulates from mine wastes. For example, the concentration of dissolved arsenic in ground waters around the unmined Bald Mountain deposit in northern Maine reaches a maximum of 430 µg/L compared to the EPA maximum contaminant limit of 50 µg/L currently under revision (Seal and others, 1998a). Likewise, a shallow ground-water well near the abandoned Elizabeth copper mine in eastern Vermont has high concentrations of copper and cadmium (Hathaway and others, 2001). At the Valzinco mine in central Virginia, fine-grained flotation mill tailings exposed to wind and water contain 4,000 ppm lead, well in excess of EPA residential and industrial soil criteria (400 and 750 ppm lead, respectively).

Ecosystem impacts associated with gold deposits are less significant than those associated with massive sulfide deposits, with the exception of gold-bearing massive sulfide deposits. Dissolved metal concentrations, including iron, are generally low because the mined deposits contained only minor amounts of sulfide minerals (Ashley, in press). However, the mercury used to recover the gold poses a significant human-health threat. In aquatic settings, mercury occurs as a variety of species. Of these, methylmercury is of greatest concern, because it is a potent neurotoxin that bioaccumulates with increasing trophic level. Thus, the primary pathway for human-health impacts is through the consumption of fish and other higher organisms in mercury-contaminated environments. In aquatic settings, the primary mechanism for methylation of mercury is as a byproduct of the metabolism of sulfate-reducing bacteria (Compeau and Bartha, 1985). In addition to mercury, arsenic derived from the weathering of arsenopyrite or arsenian pyrite can pose human-health threats by contaminating ground-water wells.

MASSIVE SULFIDE DEPOSITS

Massive sulfide deposits exhibit a range of behaviors in surficial environments. Some of the characteristics are representative of massive sulfide deposits as a group, whereas others reflect the type of massive sulfide deposit, and yet others are unique to specific deposits, arising from specific details of the local geology or mining and ore-processing methods used.

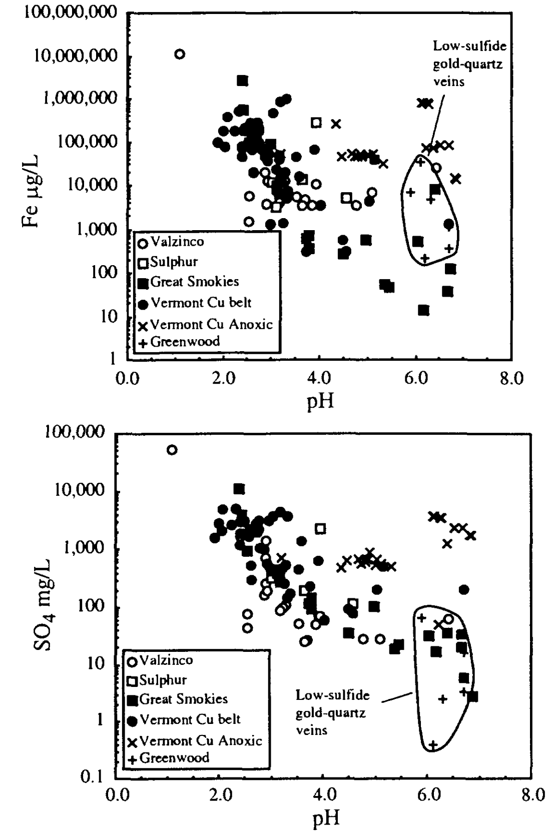

Figure 2. Plot of dissolved iron and sulfate versus pH for mine drainage from Kuroko- (open symbols) and Besshi-type (filled symbols) massive sulfide deposits and low-sulfide gold-quartz vein deposits.

Wall rocks of abandoned mine workings and waste from massive sulfide deposits generate acid-sulfate drainage with high concentrations of iron (Fig. 2). Thus, the abundance of pyrite and pyrrhotite is distinctly reflected in the drainage chemistry of this group of mineral deposits. However, differences between typical pyrrhotite-rich Besshi-type deposits and pyrite-rich Kuroko-type deposits are most apparent in settings where the access of atmospheric or dissolved oxygen is limited, but are less obvious in oxygenated settings. The reason for this distinction can be seen by comparing reactions 1 and 2 above. The oxidative weathering of pyrrhotite only generates a limited amount of acid, proportional to the nonstoichiometry of the mineral relative to ideal FeS. Thus, pyrrhotite-rich mines or waste piles where the supply of oxygen is limited, such as in the mine pool or tailings piles at the Elizabeth mine, can produce waters with high concentrations of iron at near-neutral conditions where the iron is dominantly in the ferrous state.

Trace metal concentrations of drainage are best considered in terms of individual elements. Plots of pH versus dissolved total base metals (Cd + Co + Cu + Ni + Pb + Zn) have been shown to be useful in distinguishing between major mineral-deposit types such as massive sulfide deposits and low-sulfide gold-quartz vein deposits (Plumlee, 1999), but they have limited utility in distinguishing among the various classes of massive sulfide deposits (Fig. 3). Differences between Kuroko-type and Besshi-type deposits are readily apparent in the zinc and copper compositions of mine waters. Zn:Cu ratios in ore from Besshi-type deposits are uniformly lower than those from Kuroko-type deposits. The difference in Zn:Cu ratios between ores of Besshi- and Kuroko-type deposits are also reflected in the mine drainage from abandoned mines in the Appalachians (Fig. 4). The Zn:Cu ratios of waters from Besshi-type deposits range from approximately 1:20 to 35:1, whereas those from Kuroko-type deposits range from 1:1 to 4,000:1. Thus, the Zn:Cu ratio is a direct manifestation of the geology of the deposit.

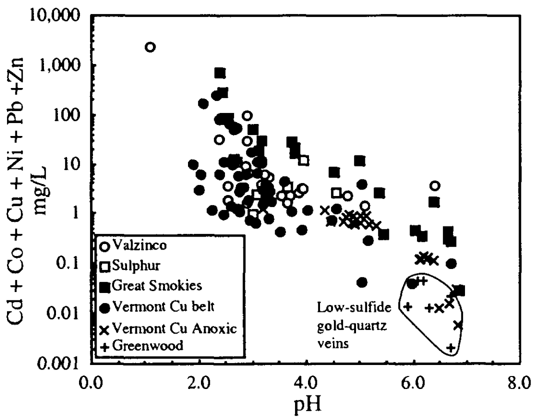

Figure 3. Plot of dissolved total base metals versus pH for mine drainage from Kuroko- (open symbols) and Besshi-type (filled symbols) massive sulfide deposits and low-sulfide gold-quartz vein deposits.

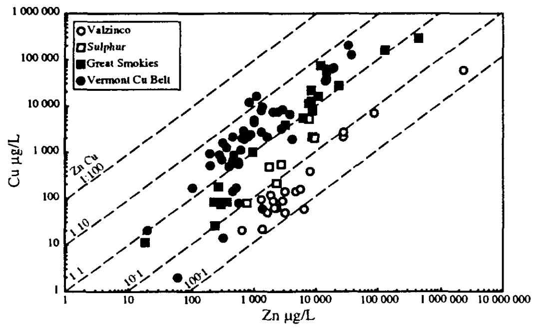

Figure 4. Dissolved copper and zinc concentrations for mine drainage associated with Kuroko- and Besshi-type massive sulfide deposits.

Compositions of other trace metals in mine drainage are influenced by the mineralogy and other characteristics of the mine waste. Mine wastes include mine dumps, flotation mill tailings piles, and smelter slags and calcine. Soluble efflorescent salts intermittently form on all of these materials, and temporarily sequester iron, aluminum, sulfur, and other metals and acidity between rainstorms. In Valzinco ores, sphalerite contains minor cadmium (0.2 wt. %) and pyrite contains minor cobalt (0.2 wt. %); these trace metals are released during weathering. Highly reactive, fine-grained pyrite (Kuroko-type) and pyrrhotite (Besshi-type) are the major sulfide minerals present in tailings. Zinc was present in many of the massive sulfide ores, but was not recovered in all cases and remains on-site in waste. Leachates from passive leach experiments (Hageman and Briggs, 2000) on slag and calcine exposed along Davis Mill Creek in the Copper Basin, Tennessee, exceed acute freshwater guidelines for copper. Pellet slag, which is used for roofing materials, released significantly higher concentrations of copper (860 µg/L vs. 26 µg/L) and zinc (400 µg/L vs. 86 µg/L) when leached with a synthetic acid rain solution instead of with deionized water.

The regional geologic setting of the deposit is also an important factor, particularly as it pertains to the alkalinity and hardness of receiving bodies of water, and how these parameters relate to vulnerability of the watershed. Host rocks of Kuroko-type deposits, such as those of the Mineral district, Virginia, are dominantly felsic and mafic submarine volcanic rocks, and siliciclastic sedimentary rocks. The hardness and alkalinity of watersheds underlain by these rocks, upstream from the impacts of mining, are low. Upstream of the Valzinco and Sulphur mines, the hardness ranges from 5.2 to 12.2 mg/L $CaCO_3$ and the alkalinity from 0 to 16.0 mg/L $CaCO_3$. In contrast, the alkalinity and hardness of watersheds hosting Besshi-type deposits is more variable. Upstream of the Elizabeth and Ely mines, Vermont, watersheds are underlain by carbonate rocks. The hardness and alkalinity upstream of mine effluents ranges from 55.3 to 128.0 mg/L $CaCO_3$, and 18.0 to 113.9 mg/L $CaCO_3$, respectively. However, in the Great Smoky Mountains National Park, watersheds have a limited amount of carbonate strata. In this area, away from the impacts of mining, the hardness (0.7 to 7.0 mg/L $CaCO_3$) and alkalinity (0 to 5.7 mg/L $CaCO_3$) are uniformly low.

GOLD DEPOSITS

Geochemical studies of the environmental impact of mercury related to historic mining in the Appalachian region are limited in both number and scope. Studies have been conducted in Alabama, Georgia, North Carolina, and Virginia. Studies of mercury speciation in surface waters in and around the abandoned Greenwood mine, a low-sulfide gold-quartz vein deposit in the Virginia gold-pyrite belt, illustrate the potential for extreme geochemical environments in Eastern settings (Fig. 1; Seal and others, 1998b, c). The mine site is at the headwaters of Quantico Creek, which empties into the Potomac River. Mercury concentrations in soils around the mine range from <0.02 ppm (background) to 692 ppm at the gold ore processing site. These mercury concentrations exceed residential (23 ppm) and industrial (610 ppm) soil screening guidelines (U.S. EPA, 2000).

Surface waters around the abandoned Greenwood mine were sampled and analyzed for their major and minor constituents (Figs. 2 and 3), including mercury speciation. The waters include samples within shaft depressions, and both upstream and downstream from the site. The waters from the shaft depressions display anomalously high dissolved concentrations of methylmercury. Ratios of methylmercury to total mercury in the dissolved fraction (up to 0.89) are also anomalous (Fig. 5). The geological and geochemical environment in shaft depressions at the Greenwood mine favors the methylation, but not the demethylation of mercury. Water in the shaft depressions is characterized by stagnant, near-neutral pH (6.3 to 6.7), low total dissolved solids (<160 mg/L), low redox potential (dissolved oxygen <1.3 mg/L), abundant organic matter, and moderate dissolved sulfate concentrations (2.5 to 16.0 mg/L). These conditions stimulate sulfate-reducing bacteria, which are the principal methylators of mercury under anoxic conditions (Compeau and Bartha, 1985). Demethylation is not favored because of anoxia and insufficient mercury and other heavy metals to induce gene transcription in microbes to detoxify methylmercury (Robinson and Tuovinen, 1984). Dissolved mercury levels are depressed because the shaft waters are saturated with respect to cinnabar (HgS); low levels of other heavy metals are characteristic of low-sulfide gold-quartz vein deposits (Ashley, in press). Within the watershed, the percentage of methylmercury rapidly decreases downstream of the shaft depressions. Dilution decreases the total concentration of total mercury and methylmercury at less than 10 km from the mine site.

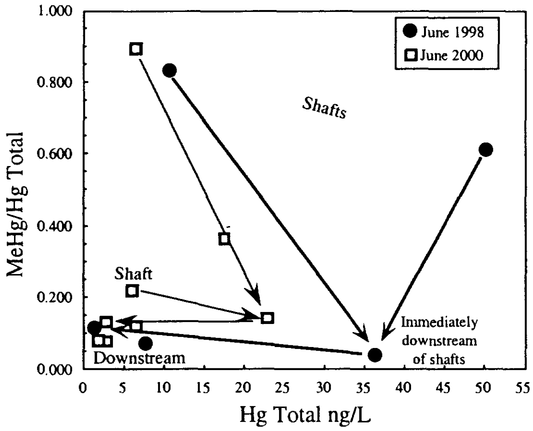

Figure 5. Plot of the proportion of methylmercury versus concentration of total mercury for the Quantico Creek watershed in the vicinity of the Greenwood mine.

Compared to mining districts in California (Ashley, in press), the waters in and around the Greenwood mine are characterized as having higher total mercury concentrations than waters of similar sulfate concentrations. The percentage of dissolved mercury to total mercury is similar to ranges reported for waters from gold districts in California. However, the percentage of methylmercury relative to total mercury in unfiltered waters near the Greenwood mine exceeds that observed in waters from mining districts in California by up to an order of magnitude (Fig. 6). The anomalous character of the mercury geochemistry of the Greenwood site can be attributed to the local environmental setting, particularly features such as deciduous vegetative cover, which provides abundant organic matter as leaf litter in the shaft depressions, and low topographic relief, which enhances stagnation of water.

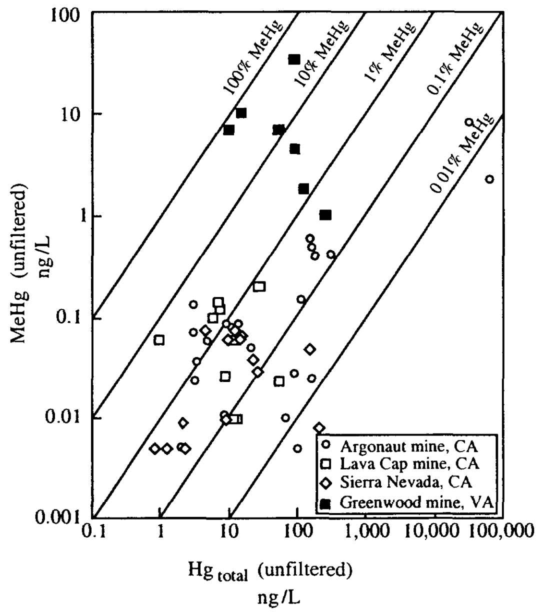

Figure 6. Comparison of methylmercury and total mercury concentrations of mine waters from the Greenwood mine with concentrations of mine waters from the Mother Lode belt, California.

DISCUSSION

For massive sulfide deposits, the associated acid-sulfate drainage with its high concentrations of dissolved iron and aluminum bears similarities to drainage associated with coal mines in the Appalachians. However, drainages associated with massive sulfide deposits have higher trace-metal concentrations than those from coal mines. Some base-metal concentrations, such as those for Cu, Zn, and Cd, vary in a predictable fashion between the two types of massive sulfide deposits found in the Appalachians on the basis of geologic and mineralogic features. Over the range of pH commonly encountered in mine drainage environments, the behavior of the individual metals can vary significantly in terms of solubility, sorption, and precipitation properties. Sorption of metals on hydrated ferric oxides (e.g., amorphous $Fe(OH)_3$, ferrihydrite, goethite) can remove significant amounts of divalent metals from solution. Lead will be sorbed almost completely on hydrated ferric oxides at pH values above 4.0, but cadmium, for example, will partition almost exclusively into solution at pH values below 5.5, and sorption will not be complete until pH exceeds 7.0 (Smith, 1999). Thus, a thorough understanding of the source, transport, and fixation processes and their variability is essential to finding remediation solutions to mine drainage problems.

Historic gold production from the Appalachian region is roughly three percent of the historic gold production from the Mother Lode belt in California (Craig and Rimstidt, 1998). Therefore, it can be expected that the total amount of mercury used in the Appalachians is also proportionally lower than that in California. Despite the much lower amount of mercury used in the Appalachians, results of our single study of mercury speciation in mine drainage in the region suggest that environments in the Appalachians that are highly conducive to mercury methylation can be established that produce proportions of methylmercury to total mercury that are one to four orders of magnitude higher than concentrations documented in California. Therefore, the total amount of methylmercury in drainages from gold mines may be higher in the Appalachians.

On a regional and global scale, there is a general correlation between the distribution of massive sulfide deposits, especially those of Kuroko type, and low-sulfide gold-quartz vein deposits, which raises possibility of adverse synergistic effects. For example, the Dahlonega and Carroll County gold belts of Georgia are generally known for their gold mines, but several massive sulfide deposits are also located in these districts; the Chestatee deposit is the largest massive sulfide in the Dahlonega belt, and the Villa Rica deposit is the largest in the Carroll County belt (German, 1989). Likewise, the Mineral district of Virginia contains both Kuroko-type massive sulfide deposits and low-sulfide gold-quartz vein deposits and associated gold placers. Contrary Creek in the Mineral district receives acid drainage from three massive sulfide mines before emptying into Lake Anna, a manmade reservoir. Downstream of the last major sulfide mine, Contrary Creek commonly has a pH around 3.7 and dissolved sulfate concentrations of about 200 mg/L. The elevated sulfate concentrations of effluent from Contrary Creek have enhanced the rate of bacterial sulfate reduction in sediments in Lake Anna (Herlihy and others, 1987). Because sulfate-reducing bacteria are the primary methylators of mercury in aquatic settings, the enhanced rate of sulfate reduction in Lake Anna caused by the elevated sulfate concentrations in Contrary Creek may be exacerbating the methylation of dissolved mercury that was originally supplied to the watershed by historic mining activity. Therefore, it is important to consider the potential interrelationships of various ore-deposit types as they relate to ecosystem and human-health risks in specific watersheds. In Lake Anna, the most likely place to find the effects of enhanced methylation of mercury is in the concentration of mercury in the tissue of large game fish.

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Tracking the Effects of Acidic Deposition in Medium-Scale Forested Watersheds of the Eastern United States

Peter S. Murdoch, U.S. Geological Survey, Troy, New York
James B. Shanley, U.S. Geological Survey, Montpelier, Vermont
Thomas Huntington, U.S. Geological Survey, Augusta, Maine

The U.S. Geological Survey Hydrologic Benchmark Network (HBN) was established in the mid-1960's for continuously monitoring flow and seasonally monitoring water quality in medium-scale naturally vegetated watersheds (100-500 km^2) throughout the United States. Unlike small watershed research sites, the HBN sites are large enough to contain well-developed riparian zones, and as such are more representative of a natural reference landscape for assessing the relative effects of air pollution, development and agriculture on water quality in the U.S. During the past 3 years more frequent water-quality monitoring (biweekly and during stormflows) has been established at five of these stations in the Eastern United States. The stations are located in eastern Tennessee (Little River, 275 km^2), western North Carolina (Cataloochee Creek, 127 km^2), north-central Pennsylvania (Young Woman's Creek, 120 km^2), southeastern and northeastern New York (Neversink River, 168 km^2), and northwestern Maine (Wild River, 180km^2), and thus lie along southeastern and northeastern gradients of decreasing sulfate deposition from west to east across the region. Concentrations of nitrate and sulfate in streamwater decrease in the northeastern sites from the southwestern-most watershed to the northeastern-most watershed. Sulfate concentrations have decreased at the Little River, Neversink River and the Wild River during the period of record, but sulfate concentrations in Young Woman's Creek and Cataloochee Creek show no trend. No trend in sulfate concentrations is evident in any of the three northeastern streams since 1995, when the last significant reduction in emissions was enacted. Sulfate concentrations in Little River have continued to fall since 1995. No trends are observed in ANC in any of the streams, but calcium concentrations in streamwater have decreased in Little River, Neversink River, and Wild River since the 60's. Calcium concentrations in streamwater decrease from a range of 80-120 µmole per liter in the northeastern streams. The stream chemistry patterns observed are similar to those in small research watersheds nested within several of the basins, and indicate that medium-scale forested watersheds are useful indicators of landscape response to changing emission standards.

Patterns of Imperilment of Southern Appalachian Fishes

Noel M. Burkhead, Stephen J. Walsh, and Robert M. Dorazio
U.S. Geological Survey, Biological Resources Division, Florida Caribbean Science Center, Gainesville, FL

North America (north of Mexico) has the richest temperate riverine ecosystems in the world. Of the 800+ freshwater fishes in the United States and Canada–about 350 species or 44 percent–occurs in the southeastern United States in the un-glaciated highlands of southern Appalachia. This diversity is paralleled in other aquatic groups, notably snails, mussels, crayfishes, and microcrustaceans. Comprised of four physiographic provinces, topographically diverse southern Appalachia is a geologically and environmentally complex area that has been a major center of evolution in the North American fishes. Southern Appalachian river systems are characterized by high diversity and in some cases, extraordinary endemism. The composition of the southern Appalachian ichthyofauna was delineated based on zoogeographic patterns of faunal breaks and endemism. The fauna includes archaic species–sturgeon, paddlefish, and gars–traceable to Pangea, and modern species virtually at the forefront of evolution.

The broad impact of human population growth on aquatic biodiversity is the basis for the Southeast being recognized as a global freshwater conservation hot spot. Imperilment of southeastern freshwater fishes is increasing. Multiple investigators estimate that present levels of imperilment to be 20 to 25 percent of the fauna. Obviously a primary conservation concern is that many declining species may become extinct, a pattern that appears evident in the beleaguered mussel fauna. Imperilment in southern Appalachian fishes was examined by comparing the imperiled and non-imperiled subsets of the fauna across multiple biological attributes that reflect basic patterns of adaptive strategies. Attributes included range size, physiographic province, stream sizes, vertical orientation in water column, trophic guilds, spawning guilds, body size, longevity, and fecundity. The resultant matrix of ~ 350 species by 48 categorical variables was analyzed by running 10,000-iteration randomized sampling of the matrix to construct a statistical model unique to the data set.

Imperilment among southern Appalachian fishes was not random relative to the ecological and habitat attributes tested. In general, small-sized, short-lived, benthic fishes with low to moderate fecundity, and small- to moderate-sized ranges are disproportionally imperiled. Secondly, some large-river, vagile fishes exhibit higher imperilment levels. Although the dire negative effects of nonindigenous fishes has largely been in the West, recent spread of non-indigenous transplants threaten listed species, and logical, testable inferences regarding how human activities relate to the observed patterns. It is inferred that excessive sedimentation is a principal cause of degradation and destruction of benthic habitats. Research investigating the effects of suspended sediment on reproductive success showed significant negative effects in a native, benthic-spawning minnow, and provides insight into the long-term effects of chronic sedimentation on population persistence and stability of benthic fishes. Biological pollution by non-indigenous transplants, especially the red shiner, may prove serious, long lasting threats to endemic fishes.

Fortuitously, creeks and rivers can inherently rebound when sources of degradation are abated. Southern Appalachian streams are far from being thoroughly investigated; indeed, new species are still being discovered. Although the diverse cultures of the southern highlands have long been recognized, appreciation of regional biological diversity is still a work in progress. While some groups of southern Appalachian fishes appear on the verge of extinction, these river systems are remarkably resilient and can recover from egregious abuses. New alliances are being made at this very moment; hopefully, new ways of addressing these complex problems are at hand.

Framework Geology and Energy Resources in the Central Appalachian Basin

Leslie F. Ruppert, Robert T. Ryder, Robert C. Milici, John E. Repetski, Linda J. Bragg, Susan J. Tewalt, Michael H. Trippi, Elizabeth L. Rowan, and Robert E. Crangle
U.S. Geological Survey, Eastern Energy Resource Team, MS 956, Reston, VA 20192

The U.S. Geological Surveys USGS) Energy Resource Program (ERP) is in the second year of funding for a five-year project which will result in a GIS-based framework to relate coal, oil, and gas resource distribution, quality, and quantity with geologic processes in the Appalachian Basin. The primary objective of the project is to understand the genetic links between geology and processes that exert significant influences on the quantity and quality of economic fossil energy resources in the basin. These processes include, but are not limited to, coal-forming processes, timing of oil and gas generation, basinal fluid migration, thermal maturation, and burial history. Information developed in this project will allow us to better forecast the distribution of fossil fuels within geologic basins in order to improve our coal, oil, and gas assessments and to better predict the economic and environmental consequences of producing and using fossil fuel resources.

The Appalachian Basin is a mature, well-studied, foreland basin with an extensive infrastructure for supporting economic development of its fossil fuel resources. Significant central Appalachian geologic and energy resource databases exist within USGS, State surveys, universities, and industry. Coal bed and petroleum systems maps and databases produced during USGS ERP National Coal Resource Assessment (NCRA) and the National Oil and Gas Assessment (NOGA) will provide the energy resource GIS coverages that are basic to understanding fossil fuels within the basin.

Five of the top-producing coal beds within the Appalachian Basin—the Pennsylvanian Pittsburgh, Upper Freeport, Lower Kittanning, Fire Clay, Pond Creek, and Pocahontas No. 3 coal beds and coal zones—were fully assessed in the NCRA project. The areal extent, structure contour, overburden thickness, and isopach thickness maps that were created to calculate original and remaining coal resources for NCRA can be directly utilized in the GIS. We will build upon this work and focus on other top-producing coal beds and those with high potential for coalbed methane production. Oil and gas plays assessed by NOGA, including the Ordovician Trenton deep gas play and numerous unconventional plays from sandstone, shale and coal, will be augmented by studies of other potentially productive intervals. In addition to the ERP data, digital stratigraphic data are available from the Eastern Region Minerals Team, structural data are available from USGS and State survey databases, and seismic data are available from a variety of sources. We are augmenting available seismic stratigraphy, regional cross-sections, and thermal maturation data with new data generated within the project. These new data, produced in fiscal year 2001 include (1) new, detailed seismic interpretations of the Dunkard Basin and underlying Rome Trough, both sub-basins of the Appalachian Basin, (2) more than 3,000 thermal maturation data points (R_o and CAI) for the Ordovician, Devonian, and Pennsylvanian strata within the basin, (3) thermal maturation maps for Ordovician and Devonian strata in Pennsylvania, and (4) digitized published and non-published regional cross-sections throughout the basin.

SESSION III

The USGS National Civil Applications Program – Supporting Federal Civil Agency Use of Classified Remote Sensing Data
Diane Eldridge

The National Biological Information Infrastructure Southern Appalachian Information Node
Mike Frame and Robb Turner

Physical Properties of Rocks of the Appalachian Region as Represented by Geochemical and Geophysical Data
Joseph S. Duval, David L. Daniels, Jeffrey N. Grossman, and Suzanne Nicholson

Eastern Region Geography Activities
Katrina B. Burke

Digital Geologic Maps, Databases, and Isotopic Data of the Appalachian Region
Scott Southworth, John Aleinikoff, Tom Armstrong, Bill Burton, Pete Chirico, Avery Drake, Wright Horton, Mike Kunk, Chuck Naeser, Nancy Naeser, Nick Ratcliffe, and Jim Reddy

A Metapopulation Analysis for Black Bears in the Southern Appalachians
Jennifer L. Murrow, Frank T. van Manen, Joseph D. Clark, and Michael R. Vaughan

Land Use Change Adjacent to Protected Areas
John D. Peine

Managing Regional Information: Lessons from Chesapeake Bay
David I. Donato

The USGS National Civil Applications Program – Supporting Federal Civil Agency Use of Classified Remote Sensing Data

Diane Eldridge
U.S. Geological Survey, MS 562- ASC, Reston, VA 20192

Since the 1960s, classified satellite imagery has been available to Federal civil agencies for their mapping and science applications. Used as an alternative data source or in combination with data collected from traditional sources, the unique capabilities of these data have proved to be valuable in a wide variety of applications that support the missions and mandates of the Federal civil agencies that are members of the Civil Applications Committee (CAC). The Department of the Interior (DOI) and all of its agencies are CAC members. Within the DOI, classified remote sensing data is used to support national mapping programs; land and resource management programs; detection and mitigation of hazards, such as earthquakes, volcanoes, forest fires, floods and hurricanes; and other scientific and environmental studies. The USGS, through its National Civil Applications Program (NCAP), supports Federal civil agency use of classified satellite imagery by providing imagery acquisition services and the use of secure facilities and data exploitation systems to all CAC member agencies. The Advanced Systems Center (ASC) and the National Center Collateral Facility (NCCF), both located at the USGS National Center in Reston, Virginia are the USGS Eastern Region secure facilities. This presentation will highlight Eastern Region projects that have made use of these unique data sources and will provide information on how to obtain and use classified data to support the programs, projects and scientific and environmental studies of the Appalachian Region.

The National Biological Information Infrastructure Southern Appalachian Information Node

Mike Frame[1] and Robb Turner[2]
[1]U.S. Geological Survey Center for Biological Informatics
[2]Southern Appalachian Information Node

The NBII program was created in 1993 based on the recommendation of a special panel convened by the National Research Council to examine critical national biological resource issues. The National Biological Information Infrastructure NBII www.nbii.gov is an electronic information network that provides access to biological data and information on our nation 's plants, animals, and ecosystems. Data and information maintained by federal, state, and local government agencies; non-government organizations; and private-sector organizations are linked through the NBII gateway and made accessible to a variety of audiences including researchers, natural resource managers, decision-makers, educators, students, and other private citizens. Recently, a team of internationally renowned scientists (which included a Nobel prize winner) spoke of the need for a next generation NBII or NBII-2. Today, work on the new NBII is underway. One of the key components of the next generation NBII is a system of nodes that is being developed to ensure broad partnerships and information from all sectors of society. These nodes function as fully digital, distributed, and interactive systems that focus on developing, acquiring, and managing content on a defined subject area (thematic nodes) or a geographic region (regional nodes). The NBII Southern Appalachian Information Node (SAIN) is one of several regional nodes established in 2001.

SAIN is the biological component of the Southern Appalachian Regional Information System (SARIS) a unique source for integrated science including biological, physico-chemical, and socio-economic data and information created and coordinated in the region. The SAIN/SARIS system combines multi-agency information and regional resources to improve productivity, resource management, and sustainable development through the Southern Appalachian Man and the Biosphere (SAMAB) program and other partners.

SAIN is a leader in issues of ecosystems informatics and biodiversity information analysis and evaluation. SAIN also takes a national responsibility to build the integrated access system and clearinghouse to distribute NBII information.

SAIN/SARIS facilitates:

- Using environmental information effectively in public-and private- sector decision making for resource management, economic development, land use and planning and policy development.
- Assessing and controlling invasive species in Southern Appalachia.
- Innovation in the dissemination of spatially enabled data and information over the Web.
- Building a coalition to get broad and deep regional participation in and support for node development.

This paper will discuss the NBII Node enterprise with an emphasis on the NBII SAIN Regional Information Node activities and initiatives.

Physical Properties of Rocks of the Appalachian Region as Represented by Geochemical and Geophysical Data

Joseph S. Duval, David L. Daniels, Jeffrey N. Grossman, and Suzanne Nicholson
U.S. Geological Survey, 954 National Center, Reston, VA 20192

ABSTRACT

The U.S. Geological Survey (USGS) has large regional databases of geochemical and geophysical data of the Appalachian region. The geochemical data available are the results of chemical analyses of stream-sediment samples. The geophysical data are aeromagnetic, aeroradiometric, and gravity data compiled using a variety of data sources and surveys. All of the data sets have been processed by the USGS to improve their internal consistency. The data are available in digital formats that facilitate their use in geographic information systems. The geochemistry data from stream sediment samples reflect the chemical characteristics of the rocks and soils, and the geophysical data reflect the density, magnetization, and surface radioactivity of the geologic materials. Both the Geochemical and geophysical data provide direct and indirect information related to the geology and geologic processes that have formed the rocks and soils.

INTRODUCTION

The U.S. Geological Survey (USGS) has compiled geochemical and geophysical data that cover most of the Appalachian region as indicated by the shaded area in figure 1.

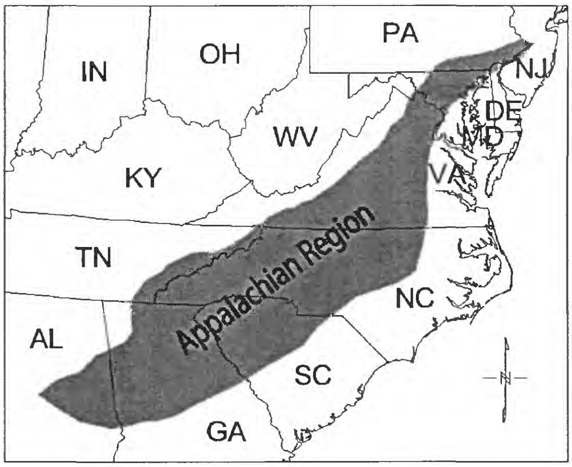

Figure 1. Shaded area shows the Appalachian region as used here.

The geochemical data presented here are based on stream-sediment samples collected as part of the National Uranium Resource Evaluation (NURE) Program of the U.S. Department of Energy from 1975 to about 1983. Uranium was analyzed during the original NURE program, mostly by delayed-neutron activation analysis. Arsenic was analyzed recently by the USGS in a subset of the same NURE samples using hydride generation atomic absorption spectrometry. The samples were extracted from a sample archive that is currently located at a USGS facility in Denver, Colorado. In addition to As, recent reanalyses also include forty major, minor, and trace elements by inductively coupled plasma-atomic emission spectrometry (ICP-AES), and mercury and selenium by atomic absorption. Arbogast (1996) provides more detailed information about the analytical methods and the elements measured. Information about the NURE Program and NURE geochemical data are available on the internet (Smith, 2000) and as a digital publication (Hoffman and Buttleman, 1994).

The aeromagnetic data presented here are from a compilation of many diverse airborne surveys and include some data digitized from contour maps. The USGS compiled the data and processed it to obtain an internally consistent database. Some of the data used in the compilation are available on the internet (USGS, 2001).

The USGS compiled the gravity data from data available from the National Geophysical Data Center (Dater and others, 1999), surveys done by the USGS, and data from the U.S. Defense Mapping Agency.

The aeroradiometric data are taken from a compilation of NURE aerial gamma-ray surveys published by Phillips and others (1993). The original aerial gamma-ray data were processed by Duval and Riggle (1999).

DISCUSSION

Figure 2 shows a generalized lithologic map of the Appalachian region based upon the map compiled by Peper and others (2001). Hatcher and others (1989) edited a series of papers that provide a broad summary of the geologic history of the Appalachian and Ouachita Mountains in the United States and should be consulted for more detailed information. The region has been divided into broad physiographic provinces (for example see Bayer, 1989) as the Blue Ridge Province, Western Piedmont, Eastern Piedmont, and the Carolina Terrain.

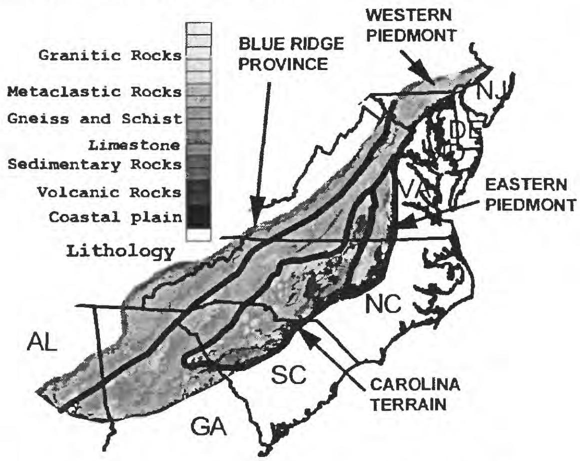

Figure 2. Generalized lithologic map based on the map published by Peper and others (2001).

Figure 3 shows the distribution of uranium in stream sediment samples (Hoffman and Buttleman, 1994; Smith, 2000). The stream sediments of the Carolina Terrain have concentrations generally less than about 3 ppm U whereas those of the Western Piedmont have concentrations greater than about 5 ppm U. The uranium in stream sediments of the Blue Ridge Province are varied but include areas of distinctly higher or lower concentrations of uranium.

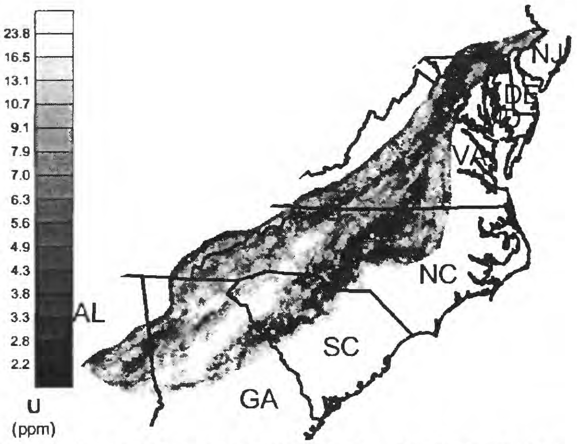

Figure 3. Uranium concentrations in stream sediment samples of the NURE Program.

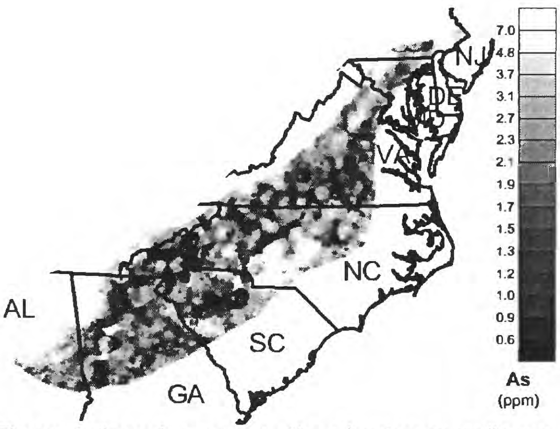

Figure 4. Arsenic concentrations in stream sediment samples of the NURE Program

Figure 4 shows the distribution of arsenic in stream sediment samples (unpublished data from USGS). Although the density of the sample coverage for arsenic is less than that for uranium, the data indicate that many of the stream sediments of the Carolina Terrain have generally higher concentrations of arsenic than other sediments in the region. The arsenic concentrations in the areas of the Blue Ridge Province, Western Piedmont, and Eastern Piedmont are varied but are generally lower than those in parts of the Carolina Terrain. The data in figures 3 and 4 suggest that the uranium and arsenic concentrations in stream sediments may have an inverse relationship for parts of the region.

Figure 5 shows the residual aeromagnetic data for the region. These data reflect the magnetite content of the rocks and many of the higher values are associated with volcanic rocks along and near the boundary between the Blue Ridge Province and the Western Piedmont, in the southern part of the Western Piedmont, and in the northern part of the Carolina Terrain. Anomalies of smaller dimensions are associated with rocks at or near the surface, gabbroic intrusives, metamorphosed volcanic rocks, and volcanic sediments. Broad, diffuse anomalies reflect deeply buried rock bodies.

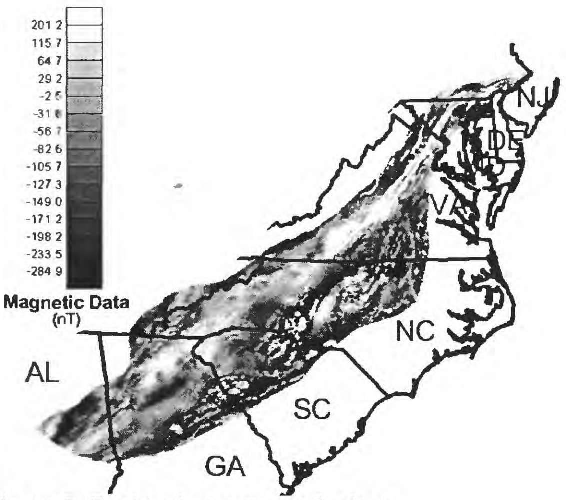

Figure 5. Residual aeromagnetic data.

Figure 6 shows the Bouguer gravity anomaly map for the region. This map largely reflects regional structures at the base of the crust. Anomalies of small dimensions reflect rocks at or close to the surface. Many of the higher values occur within the Carolina Terrain. The lowest gravity values are in the west-central part of the region. This gravity low is part of a broad area of lower gravity west of the Appalachian region.

Figures 7, 8, and 9 show the potassium, uranium, and thorium concentrations in the rocks and soils as measured by the aerial gamma-ray surveys of the NURE Program. The uranium and thorium concentrations are reported as equivalent uranium (eU) and equivalent thorium (eTh) because the gamma-ray data measure daughter products of the radioactive decay series rather than the parent uranium and thorium. Both uranium and thorium have relatively continuous bands of higher concentrations (greater than about 2.5 ppm eU and 9.0 ppm eTh) within the area of the Western Piedmont. These bands do not exhibit any apparent correlation with potassium. The rocks within these bands are paragneisses and the uranium-thorium signature may reflect the presence of abundant monazite formed during the metamorphic process or inherited from the original rock.

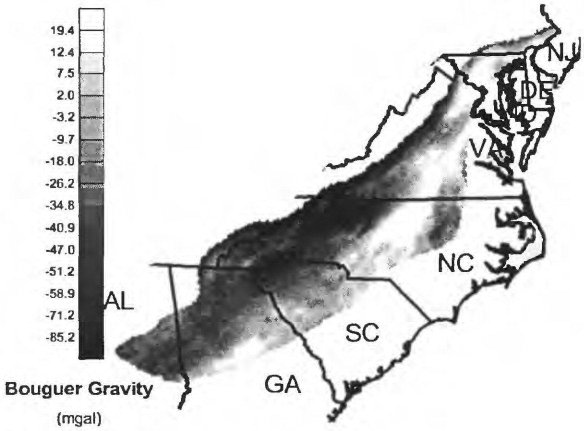

Figure 6. Bouguer gravity anomalies.

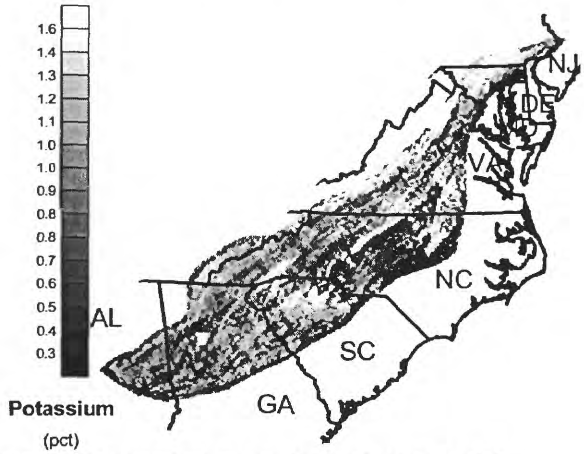

Figure 7. Potassium concentrations from aerial gamma-ray surveys of the NURE Program.

The potassium data do show an oval area of generally higher concentrations in northern South Carolina. Within this oval area the uranium and thorium data exhibit patterns that are similar to one another but distinct from the pattern of the potassium data. The geologic map shows abundant intrusive bodies of granite within the same area. The uranium and thorium patterns may be related to the granites but the regional potassium high suggests a regional enrichment of potassium.

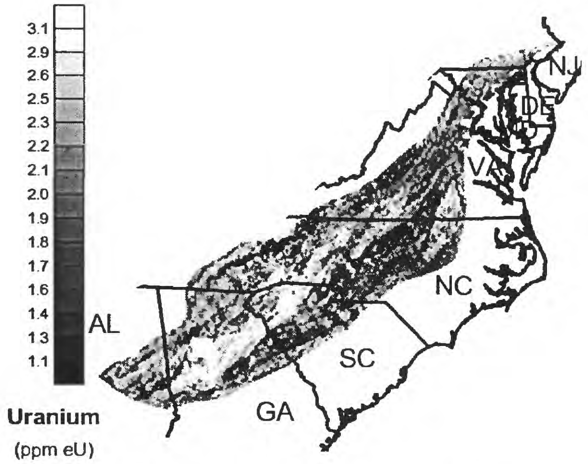

Figure 8. Uranium concentrations from aerial gamma-ray surveys of the NURE Program.

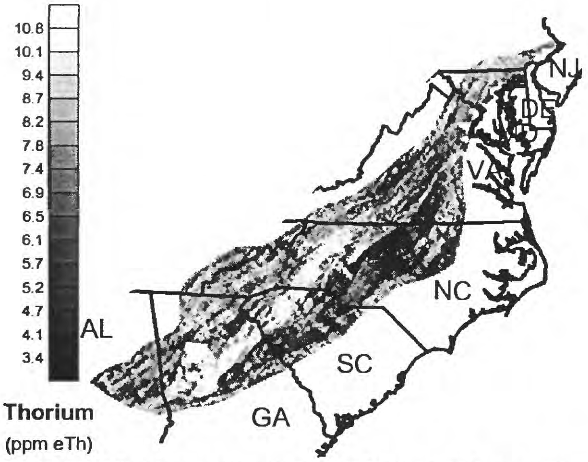

Figure 9. Thorium concentrations from aerial gamma-ray surveys of the NURE Program.

CONCLUSIONS

Extensive geophysical and geochemical data are available for the Appalachian region in a variety of digital formats. These data can be used, analyzed, and compared to an almost endless variety of other types of data. The geophysical data provide both direct and indirect indicators of the geology and geologic processes that have formed the rocks and soils present in the region. The geochemical data from stream-sediment samples reflect the chemical characteristics of the rocks and soils. Because the distribution of uranium from the geochemical uranium data (figure 3) show excellent agreement with the distribution of uranium from the aerial gamma-ray surveys supports, we conclude that the stream sediment samples have a dominant component derived from local rocks and soils. Together the geochemical and geophysical data represent valuable information that can significantly contribute to a variety of geological and environmental studies.

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Eastern Region Geography Activities

Katrina B. Burke
U.S. Geological Survey, 559 National Center, Reston, Virginia 20192

The U.S. Geological Survey (USGS) fosters and promotes cooperation among Federal, State and local agencies, academia, and the private sector collect and produces geospatial data. Eastern Region Geography partnership activities cover the requirements of Federal agencies, regional consortia, 26 eastern states, and two territories (Puerto Rico and Virgin Islands). For more than 100 years the National Mapping Program has been partnered with the States and has contributed to producing geospatial products such as aerial photos, digital orthophoto quadrangles (DOQ), digital elevation models (DEM), digital line graphs (DLG) and the National Hydrography Dataset (NHD).

The USGS is working on projects at a variety of scales throughout the Eastern Region. North Carolina has projects that, include 1:12,000-scale color infra-red DOQs, Light Detection and Ranging (LIDAR) for Digital Flood Insurance Rate Maps (DFIRM), Photoinspection, and Graphic Revision; Kentucky is cooperatively producing statewide coverages for DOQs and DEMs, a revised hydrography data layer, and an NHD. A State Base map program in Tennessee is acquiring high-resolution statewide data coverages. The data themes being considered for production are imagery, DOQs, DEMs, and various planimetric layers. In Vermont a 1:24,000-scale NHD will be used to model flood frequency and to plan bridge replacements and road improvements. In Michigan, the completion of second- generation DOQs is underway for the preparation of a State digital base map. Additional projects are ongoing throughout the Eastern Region States to support 10-meter DEMs, Graphic Revision, statewide NHD, revised contours, and NAPP.

Through partnerships, the USGS is able to increase collection, application, and dissemination of data that benefit the public. The USGS is actively seeking for opportunities to build new alliances to decrease data redundancy and develop initiatives by working together within the States and the Regions. Such collaboration facilitates the acquisition of data needs to resolve earth science, social, and economic issues that have an effect on partnering agencies.

Digital Geologic Maps, Databases, and Isotopic Data of the Appalachian Region

Scott Southworth, John Aleinikoff, Tom Armstrong, Bill Burton, Pete Chirico, Avery Drake, Wright Horton, Mike Kunk, Chuck Naeser, Nancy Naeser, Nick Ratcliffe, and Jim Reddy

The Appalachian Regional Geology and Hydrology (ARGH) Project is completing geologic maps and databases that build on several decades of geologic mapping and field-based research. Funded by the National Cooperative Geologic Mapping Program, we have contributed to the publication of geologic maps of the States of MA, NH, NJ, and VA, while publishing quadrangle geologic maps of 1:250,000-, 1:100,000-, 1:50,000-, and 1:24,000-scale in VT, PA, NJ, MD, VA, D.C., WVA, NC, SC, TN, GA, and AL. Currently we are making a series of geologic maps of the Washington-Baltimore region, select National Parks, and Vermont.

Detailed geologic map coverage does not exist for much of the Appalachian region, yet regional investigations require the detailed data in a digital format. Our long-term goal is to provide the detailed geologic database of the Appalachian region by focusing on high-priority areas for maximum scientific and societal benefit. We will illustrate the importance of accuracy of our geologic map data and utility of our database of the National Capital Region by comparing them with existing regional-scale digital geologic maps of the Appalachian region such as the National Atlas, Tapestry, Lithology map.

We are now developing a new generation of digital geologic maps and databases in a geographic information systems (GIS) format for intergrated, multidisciplinary research. Field data collected at 1:24,000-scale or larger are published and released on the internet as digital files at 1:24,000- and 1:100,000-scale, with corresponding high-resolution DEM and aeromagnetic data. We are investigating historical topographic change in urban areas as well as researching innovative GIS applications of geologic, geophysical, and other data. Successful applications of the digital geologic data by others include 1) the cost benefit analysis of the Loudoun County, Va., landfill, 2) the production of new soil maps in the Blue Ridge and Piedmont of Virginia and Maryland, 3) land-use ordinances in Loudoun County, Va., based on karst in the Mesozoic Culpeper basin, 4) the statistical correlation of well water yield to bedrock units in the Blue Ridge province of northern Virginia, and 5) the identification of habitats favorable for endangered plant communities in park lands.

Our increased understanding of this bedrock framework supports a detailed investigation of the structural, thermal, and uplift history along several transects across the central Appalachians from the Atlantic Coastal Plain province west to the Appalachian Plateaus province. We are determining the U-Pb crystallization ages of zircons and other minerals in igneous rocks that could not be reliably dated by earlier methods using the high-resolution ion microprobe to better establish geochronology in complex settings of the Piedmont and Blue Ridge. We are also analyzing 40Ar/39Ar release spectra in mica and hornblende and fission tracks in apatite and zircon to determine the timing and conditions of Paleozoic metamorphism and cooling due to fault motion, uplift and erosion.

A Metapopulation Analysis for Black Bears in the Southern Appalachians

Jennifer L. Murrow[1], Frank T. van Manen[2], Joseph D. Clark[2], and Michael R. Vaughan[3]
[1]Department of Forestry, Wildlife and Fisheries, University of Tennessee, P.O. Box 1071, Knoxville, TN 37901, USA
[2]U. S. Geological Survey, Southern Appalachian Field Laboratory, 274 Ellington Plant Sciences Building, University of Tennessee, Knoxville, TN 37996, USA
[3]Virginia Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic and State University, 148 Cheatham Hall, Blacksburg, VA 24061-0321, USA

Black bear (*Ursus americanus*) populations in the southern Appalachians are fragmented and may function as a metapopulation, with local extinctions and colonizations being dependent on habitat patch size and distribution. To determine whether such a relationship existed, we used an incidence function model developed by Hanski (1993) whereby, given bear presence/absence data and information on patch size and distribution, colonization and extinction rates for individual patches might be estimated. We acquired >10,000 black bear radiotelemetry locations from studies conducted in North Carolina, Tennessee, and Virginia and determined land-cover associations based on the Multi-Resolution Land-Cover database. Those land-cover types were used to delineate habitat patches at various spatial scales and resolutions (analysis units ranged from 5 km^2 to 300 km^2 in size). Occupancy of each patch was then determined based on adult female black bear distribution data obtained from state and federal biologists. We used non-linear regression to estimate 3 extinction and colonization parameters to predict species occurrence for a given habitat patch. The regression analyses produced significant models ($P < 0.001$, R^2=0.69–0.90) for all spatial scales. As patch area increased and isolation decreased, the probability of occupancy by bears increased. These results support the hypothesis that metapopulation theory is useful to explain the spatial distribution and source-sink dynamics of black bears in the southern Appalachians. Our study suggests that the isolation of habitat patches and, to a lesser extent, their size may warrant more consideration when making management decisions. To illustrate the applicability of the model, we compared prospective sites for black bear reintroduction in the southern Appalachians.

Land Use Change Adjacent to Protected Areas

John D. Peine
USGS-Leetown Science Center, Southern Appalachian Field Laboratory, University of Tennessee at Knoxville

Resource managers of protected natural areas are becoming more concerned with human activity occurring on adjacent lands and within the context of the associated bio-geographic region. The source of a wide variety of threats to natural resources in protected areas and the aesthetics of the visitor experience is routinely attributed to human activities on adjacent lands. Threats to natural resources include habitat fragmentation; barriers to movement; interruptions of ecological continuums associated with elevational gradients; increased probability of introduced pests, pathogens and exotic species; introduction of pollution; baiting of wildlife; and increased public access to the perimeter of the protected area. Aesthetic threats include degradation of viewsheds due to development; light, noise haze pollution; and traffic congestion. As more people live adjacent to protected areas, potential hazards to humans include threats from wild fires, settlement in flash flood zones, and injury or infection from wildlife. This project relates directly to rapid development, or sprawl, a growing concern and immerging political issue. In the Appalachian Mountains, development pressure is most extreme on the fringes of metropolitan areas, in the vicinity of tourist areas, and adjacent to protected areas such as national forests and parks.

The objective of the research is to devise a methodology to characterize adjacent lands and the landscape setting of protected areas in the context of a thematic framework. This characterization will allow managers of protected areas to be better informed as to the dynamics of adjacent land use and policy, and existing and potential environmental and aesthetic impacts both inside and outside the protected area boundary. The intent is to empower resource managers through information, to be proactive in influencing public policy outside their protected area boundaries.

Themes of the interdisciplinary framework include ecosystem descriptors, land use/land cover, water resources, human dimensions, environmental conditions, and resource stewardship. The importance of public policy analysis concerning resource stewardship immerged during the course of the study. The scope of the study is to primarily utilize readily available national databases so that the methodology can be replicated. The exception is the resources stewardship theme reflecting state and local policies and programs. The intent is to focus on a general characterization of trends that may suggest current and emerging issues of concern. A limitation of the study is that the characterization is too general to infer impact analysis for biological communities let alone individual species. Incite gained from the analysis, however will provide guidance for designing a more specific study on a particular issue of concern.

Several indicators have been identified for each of the following subthemes.

- Ecosystem Theme
  - Geographic provinces
  - Bailey's ecoregions
  - Topography
- Land cover/use Theme
  - Land cover types
  - Habitat fragmentation
  - Agriculture
  - Recreational setting
  - Selected habitats
- Water Resources Theme
  - Rivers and streams
  - Wetlands
  - Riparian zones/habitat

- Lakes/impoundments
- Human Dimension Theme
  - Population dynamics
  - Social conditions
  - Social order
  - Economic dependencies
- Human Imprint
  - Resource utilization
  - Point source pollution
  - Non-point source pollution
  - Water quality
  - Exotic pests, pathogens and invasive species
  - Vehicular traffic
- Resource Stewardship Theme
  - Water resource policies
  - Terrestrial resource policies

As a case study, the proposed framework is being applied to the lands surrounding Great Smoky Mountains National Park, the Nation's most visited national park. This is an appropriate test case since several issues related to adjacent lands occur in the area. Concerns range from regional haze obscuring views of the mountains to air pollution impacting the health of vascular plants, local residents and park visitors. Traffic congestion and road construction to alleviate the problem are very controversial. Viewsheds extending outside the park boundaries are compromised by new development. Noise pollution from tourist helicopters has increased. Light pollution from increased development has further intruded on the dark sky sanctuary in the park. Major road construction projects have been delayed in two gateway communities due to controversy. As more development occurs on adjacent land, human conflicts with wildlife have increased. Human-bear interaction is the most serious concern.

The rivers flowing out of the national park provide graphic indicators of land use change. Water quality of three of the four rivers after leaving the western slope of the park does not meet the state standards for their designated use. The elevational gradient and stream order continuums are highly disrupted in terms of water quality and aquatic and riparian habitats. Fecal coliform, runoff from impervious surfaces, and sedimentation are the major sources of pollution. Use of water from these rivers for urban and industrial purposes is another issue.

The geographic focal point of concern is a 24-mile long tourist corridor that has spurred very rapid economic development and population growth. The southern terminus of this north-south corridor is the gateway community of Gatlinburg, TN. Three of the four other four gateway communities to the park provide a stark contrast where much less change has occurred. The contrast among the human dimensions indicators at the county level is particularly dramatic.

The most difficult, yet revealing part of the case study has been the policy analysis of land use and waterquality. Though there are a considerable number of progressive policies in place at the community level, their geographic limitations and lack of uniformity of compliance prove to be significant constraints to effective management of adjacent lands.

The black bear is utilized as an exemplar species to demonstrate the interdisciplinary nature of the impacts from rapid change in adjacent land use. The complexity and interdisciplinary nature of adjacent lands dynamics is reflected in the issues related to black bears. The interaction of the following influential factors on black bear behavior illustrates the complexity: their ecology and population dynamics; their utilization of adjacent lands, particularly during times of scarce natural food sources; their interaction with humans; and the policies to manage them at the federal, state and community levels.

Managing Regional Information: Lessons from Chesapeake Bay

David I. Donato
U.S. Geological Survey, 509 National Center, Reston, VA 20192

In any scientific study involving numerous investigators, information is both the raw material of the scientific process and it is the ultimate product. The effective management and sharing of a diverse information base, such as that which will be input into and generated by the multi-disciplinary Appalachian regional study, requires a customized and adaptable framework of information systems and software tools. Information managers must understand and tailor solutions for the specific requirements of the particular users they serve, avoiding the temptation to address user needs, which are too broad or too diverse. Plans for the management of data and information must, from the outset, be made an integral part of the total science plan for any study entailing substantial and distributed information-management activities. Information-management experiences in the Chesapeake Bay Program (a program related to the Appalachian region by geography and shared scientific concerns) offer lessons applicable to Appalachian science.

SESSION IV

Using Geology to Understand Flora, Fauna, and the Evolution of the Great Smoky Mountain Region
Scott Southworth, Art Schultz, Chuck Naeser, Nancy Naeser, Pete Chirico, Ari Matmon, Paul Bierman, and Milan Pavich

A Model to Predict the Occurrence of Surviving Butternut Trees in the Southern Blue Ridge Mountains
Frank T. van Manen, Joseph D. Clark, Scott E. Schlarbaum, Kristine Johnson, and Glenn Taylor

Appalachia – An Endemic Area for La Crosse Encephalitis?
Stephen C. Guptill

Abstract not available – Effects of Human Activities on Ecosystem Health: Ca Depletion
Norman Peters, Thomas Bullen, Thomas Huntington, and Gregory Lawrence

Geologic Aspects of Karst in the Appalachians
Randall C. Orndorff, Jack B. Epstein, David J. Weary, and George E. Harlow

Flood of July 2001 in West Virginia
Ronald D. Evaldi

Using Geology to Understand Flora, Fauna, and the Evolution of the Great Smoky Mountain Region

Scott Southworth, Art Schultz, Chuck Naeser, Nancy Naeser, Pete Chirico, Ari Matmon, Paul Bierman, and Milan Pavich

Geology shapes the range of topography, watersheds, and soils that host the plant and animal communities as a function of climate, elevation, and the composition and chemistry of underlying materials. We are making a digital surficial and bedrock geologic map and database in a geographic information systems (GIS) format for interdisciplinary research in cooperation with the Biological Resources Discipline of USGS, National Park Service (NPS), Natural Resource Conservation Service, and The Nature Conservancy. We are integrating our geologic research with the All Taxonomy Biodiversity Inventory (ATBI) while supporting the Inventory and Monitoring, Resource Management, and Interpretation Programs of the NPS.

Our regional database is based on 1:24,000-scale field data from Knoxville, Tenn., southeast to Waynesville, N.C., that is being integrated with digital elevation model data to interpret the complex relationship between parent material, regolith, soils, flora, and fauna. In this area, regolith far exceeds the area of exposed bedrock and most of it has been transported and deposited by water (alluvium) and gravity (colluvium and debris flows). Much of this surficial material was not derived from the immediate underlying bedrock and slope deposits differ as a function of parent bedrock. Specific bedrock and surficial materials develop specific soils, flora, and fauna; examples include mollusks on limestone, purple spurge on gneiss regolith, cardamine, yellowood, and bunchflower on meta-sandstone boulder fields, and rare plant communities on mafic, ultramafic, and sulfidic rocks. Therefore we are mapping the diverse types of rock and surface materials, to provide a useful tool to help describe and understand the distribution of plants and animals. Classifying the bedrock and surficial materials by mineral abundance and general chemical composition defines "lithogeochemical" units that also help portray different soil types and differing acid neutralization capacity of streams (a measure of their sensitivity to acidification).

Research plans will determine the topographic signatures of surficial material types throughout the study area. Topographic signatures of slope, aspect, and curvature values will be quantitatively derived from the digital elevation model (DEM) data in a GIS analysis. Quantifying topographic parameters of surficial units will aid in understanding the relationship of surficial geologic materials to soil formation and flora and fauna diversity. The methodology developed may be applied to study areas throughout the Appalachian region for analyzing spatial correlation of surfical geologic materials and topography.

Our geologic research includes 1) the distribution and characterization of sulfidic slate recognized throughout the Great Smoky Group, 2) the inventory and setting of prehistoric and historic debris flows at high elevations on steep slopes underlain by slate and the subsequent affect of acid drainage, 3) the age and genesis of slope deposits, 4) characterization of karst in structural windows, 5) the tectonic evolution of the polymetamorphic rocks of the western Blue Ridge province, and 6) the crustal framework of the East Tennessee Seismic Zone, uplift history, and rates of erosion.

Existing mica, hornblende, and slate whole-rock 40Ar/39Ar analysis suggest that the rocks of the highlands of the Great Smoky Mountains and foothills to the northwest were metamorphosed in the Ordovician and Devonian and then transported west along the Great Smoky fault in post-Mississippian time. Fission-track analysis of detrital apatite and zircon in these rocks is helping define the Permian to Cenozoic thermal and structural history. Zircon fission-track data suggest that the rocks of the highlands and similar metasedimentary rocks of the foothills were at different crustal levels prior to Alleghanian thrust faulting. Emplacement of the Great Smoky thrust sheet was early Permian, and contractional faults that cut the sheet were active after the Cretaceous. Cosmogenic 10Be in quartz from stream sediment and ridge outcrops, historical sediment yield data, and denudation rates calculated from fission tracks indicate similar rates of erosion, about 16 to 30 m/m.y., over both time and space. The similar spatial and temporal erosion rates over the last 150 million years suggests that there has been no rapid recent uplift and incision and suggests landscape equilibrium with rock type and setting.

A Model to Predict the Occurrence of Surviving Butternut Trees in the Southern Blue Ridge Mountains

Frank T. van Manen[1], Joseph D. Clark[1], Scott E. Schlarbaum[2],
Kristine Johnson[3], and Glenn Taylor[3]
[1]Southern Appalachian Field Laboratory, U. S. Geological Survey, 274 Ellington Plant Sciences Building, The University of Tennessee, Knoxville, TN 37996, USA
[2]Department of Forestry, Wildlife and Fisheries, The University of Tennessee, P.O. Box 1071, Knoxville, TN 37901, USA
[3]National Park Service, Great Smoky Mountains National Park, 107 Park Headquarters Road, Gatlinburg, TN 37738, USA

Butternut (*Juglans cinerea*) is a hardwood species native to eastern North America and is valued for high-quality lumber and as a mast source for wildlife. Many butternut populations are currently being devastated by an exotic fungus (*Sirococcus clavigignenti-juglandacearum*), which causes multiple cankers that girdle the tree and cause mortality. The decimation of butternut populations has been severe in many areas, particularly in the southeastern United States. A breeding program involving resistant genotypes might be a feasible strategy to conserve and eventually reintroduce the species. However, such an effort is critically dependent on the ability to locate enough disease-resistant stock for evaluation and subsequent breeding. We developed a data-based model to predict probable occurrence of surviving butternut trees. Field surveyors initially mapped 134 sites with surviving butternut trees in Great Smoky Mountains National Park (GSMNP). These locations were entered into a geographic information system (GIS) and overlayed with digital map layers of eleven different geographic variables that described the topographical and biological conditions at each sampling point. We then calculated the Mahalanobis distance statistic, a multivariate measure of dissimilarity, for each 92.9- × 92.9-m pixel in a 31,235-km^2 region encompassing the southern Blue Ridge Mountains to predict the relative likelihood of species presence. We then tested this model with independent presence/absence data from 130 test sites in this region as the dependent variable and Mahalanobis distance as the independent variable. We found that the Mahalanobis distance statistic showed a significant relationship with occurrence of butternut in the region. Although the field tests indicated that the species often was absent in areas predicted to be good butternut habitat, butternut decline due to the canker also may have contributed to that outcome. Biometric models such as the one we developed can be used by resource managers for collection purposes, restoration efforts, and to identify habitat associations across large areas.

Appalachia – An Endemic Area For La Crosse Encephalitis?

Stephen C. Guptill
U.S. Geological Survey, 521 National Center, Reston, VA 20192

For centuries, people have been intuitively aware of the relationships between human health and the environment. Today, geographic information systems, remote sensing satellites and other technologies are providing scientists with the tools and the data to make clear the geographic relationships between the habitats of disease agents, their vectors and vertebrate hosts, and the occurrence of disease in the human population. Although the utility of the foregoing tools as an aid to epidemiology was pointed out nearly 30 years ago, the medical community has been slow to put them to use. That may soon change as geographers, entomologists, epidemiologists, and spatial statisticians jointly focus their expertise on specific health issues.

A program of joint research is underway with scientists at the U.S. Geological Survey, the Centers for Disease Control and Prevention, and state health agencies, to examine the environmental influences on vector-borne diseases (such as Lyme disease, plague, and viral encephalitis). Specifically we are utilizing geographic information systems, remote sensing, and spatial analysis tools to:

- Define geographic distributions of disease cases and relationships to environmental factors.
- Develop and test a model predicting disease activity and transmission rates.
- Characterize the human population at risk.
- Devise ecology-based prevention and control measures.

In this presentation, we use the La Crosse encephalitis virus-vector-host system to demonstrate the current and potential uses of geographic information science and related technologies for the surveillance, prevention, and control of disease. Cases of La Crosse encephalitis recently have been concentrated within the Appalachian region of the United States, particularly in southern Ohio, West Virginia, Tennessee, and North Carolina. Are there particular ecological or socio-economic factors that cause children in Appalachia to be at greater risk for La Crosse encephalitis than in other parts of the country?

USGS, CDC, the West Virginia Department of Health, and Virginia Tech University scientists are engaged in a comprehensive study of the ecology and epidemiology of La Crosse encephalitis in West Virginia. Components of the study include case finding, serologic surveys, vector and vertebrate ecology, and public education. Precisely located (by GPS) mosquito sampling sites and human case residences provide "ground truth" data for calibration of remotely sensed data.

Our studies to date have shown that the landscapes surrounding case locations of the disease are dominated by a mixture of deciduous forest and pasture land. However, this fourteen-class categorization of land cover appears to be insufficient to discriminate positive and negative ovitrap sites placed throughout the study area. Additional geospatial data sets are being incorporated into the analysis to increase the discrimination power. Also socio-economic data are being analyzed to determine their utility as predictors of disease risk.

Geologic Aspects of Karst in the Appalachians

Randall C. Orndorff[1], Jack B. Epstein[1], David J. Weary[1], and George E. Harlow[2]
[1]U.S. Geological Survey, National Center, MS926A, Reston, VA 20192
[2]U.S. Geological Survey, 1730 East Parham Road, Richmond, VA 23228

Solution of relatively soluble rocks, such as limestone, dolomite, and gypsum, produces a terrain termed *karst* that is characterized by a variety of features, including caves, springs, sinking streams, and sinkholes. Ground-water movement may be very rapid through enlarged conduits, making shallow aquifers in karst extremely vulnerable to contamination from both point and non-point sources. Residual soil, which may plug sinkholes, can collapse and cause considerable destruction to homes, buildings, roads, railroads, impoundments, etc. Many millions of dollars in damage annually occurs in the U.S. from such collapse. Thus, understanding geologic controls on karst development is of national significance. This understanding can be accomplished by preparing maps that outline karst areas, by researching the processes that localize karst development, and by presenting this information in a manner useful for hazard mitigation.

A new project entitled Karst and Subsidence Hazards has been proposed to the National Cooperative Geologic Mapping Program. The main goal of this karst project is to produce geologic maps at a variety of scales, ranging from 1:24,000 to 1:7,500,000 that will form the foundation for developing new techniques and methods to better understand geologic controls on karst systems. Derivative maps and research papers will characterize the relationship of geologic structure and stratigraphy to karst development. A variety of tasks will be addressed: (1) ground-water contamination, (2) sinkhole formation, (3) development of new techniques for analyzing karst through remote sensing and geophysics, (4) identifying regional karst issues by producing a karst map of the Appalachians, and (5) addressing national issues through development of a new National Atlas karst map. New techniques will be used to address karst-subsidence hazards and ground-water contamination issues at local, regional, and national levels. These data will be presented to aid researchers and land-use managers in hazard mitigation and environmental protection.

One specific task involves detailed geologic mapping in the northern Shenandoah Valley of Virginia and West Virginia in the area of a major karst aquifer. A hydrogeologic framework will be determined through analysis of conduits and fractures and their relationship to springs, sinkholes, caves, and losing streams determined through a karst inventory. The geologic information will then be compared with water data to assess geologic controls on ground-water movement, storage, and quality. For example, water quality and quantity data can be correlated to stratigraphy and lithologies in order to investigate any relationships between hydrology and geology. A karst inventory will be produced by several methods of remote sensing that will include maps of sinkholes and surface basins that drain to sinkholes. This karst inventory will be compiled on geologic maps to evaluate geologic controls on karst development such as comparison to structures and stratigraphy.

Karstic rocks underlie about one-quarter of the land area of the U.S. In order to educate government managers and the public to the distribution of karst at the national and regional scales, a digital map of karst will be produced for the National Atlas at a scale of 1:7,500,000. Federal agencies (National Park Service, Bureau of Land Management, National Forest Service) have expressed an interest in combining a national karst map with one showing Federal lands. This map will be useful in determining which Federal facilities may have karst resources within their borders, especially those facilities that are unaware of it.

A detailed map of the Appalachian highlands will be the beginning of the national map. The effects of stratigraphic and structural control on karst development in this classic fold-fault belt of highly fractured rock will be researched and areas of importance delineated for further biologic, hydrologic, and geologic research. Karst features that may be included on the map are: exposed soluble rocks, including limestone, dolomite, and evaporites; intrastratal karst; karstic rocks beneath surficial overburden; percentage area covered by karst; and features analogous to karst, so-called "pseudokarst".

Flood of July 2001 in West Virginia

Ronald D. Evaldi
U.S. Geological Survey, Charleston, West Virginia

ABSTRACT

Rainfall of 3 to 6 inches during 5 to 6 hours in localized mountainous areas of Southern West Virginia on July 8, 2001 caused extensive flood damage. The U.S. Geological Survey (USGS) was active in assessing the magnitude and frequency of the flood at streamflow gaging stations and in several communities damaged by the flood. The intense rainfall caused debris flows and landslides in some areas which USGS researchers examined by overflights. Speculation that mountaintop-removal coal mining may have increased runoff rates has led to a USGS study comparing peak discharge from mined and unmined drainage basins. Studies are needed to evaluate flood reduction benefits and environmental costs of channel dredging projects. Reliability of surface water supplies susceptible to contamination from floodwaters and sediment transport during floods are areas of possible future USGS investigation.

INTRODUCTION

In the early morning hours of Sunday July 8, 2001, severe flooding and landslides caused by intense rainfall occurred in the Tug Fork and Guyandotte River Basins of Southern West Virginia. The flood caused two deaths and extensive property damage. The rain was the result of isolated thunderstorms that repeatedly formed and moved along near-identical tracks. Orographic lifting resulted in greatest rainfall intensity in the highest mountain elevations which form the headwaters of the drainage basins. Rainfall totals, as reported by the National Weather Service, were as great as 3 to 6 inches during a 5 to 6 hour period. Flooding was most severe in the small 1st and 2nd order streams. Stream levels rose rapidly allowing very little time for warnings. Rescuers used boats to save several people from floating mobile homes, and many people spent hours waiting on tops of roofs for rescue.

The counties most affected by the July 8, 2001 flooding were Boone, Fayette, McDowell, Mercer, Raleigh and Wyoming. Since the mid 1960's, each of these counties has been declared a Federal disaster area from 7 to 11 times because of flood damage. Most homes and business structures are built along stream valleys simply because that is where the only flat ground is located. Over 1,000 homes and about 700 other structures were destroyed. In addition, many roads were closed either because of floodwaters or mudslides. Several bridges were washed out.

USGS FLOOD RESPONSE

The U.S. Geological Survey (USGS) played an active role in obtaining information for flood mitigation and recovery and in developing studies on causes and consequences of the flood. This paper describes these USGS activities following the July 8, 2001 flood event in relation to ongoing data programs, Federal agency assistance, and interpretive studies.

Streamflow Gaging

The USGS streamflow gaging program is an integral part of every Water Resources Discipline office. The network in West Virginia consists of about 110 gaging stations with 91 of these transmitting data once every 4 hours via satellite which is then served over the Internet (http://water.usgs.gov/nwis). Flood plans are updated each year to determine discharge measurements necessary to define and maintain the stage-discharge ratings. Review of the Internet data on Sunday afternoon showed that new record flows had occurred at some gaging stations in Southern West Virginia. The flood plan was activated. Immediate response was not possible on Sunday because roads in the flood area were closed due to high water and mudslides. Field technicians were advised to be prepared for overnight travel for the upcomming week and a Project Alert description of the flood situation was transmitted to USGS Headquarters.

Review of the Internet data early Monday morning revealed that the July 8 flood event had receded in the headwaters area of the Tug and the Guyandotte Basins (fig. 1) and that the flood wave was dissipating as it progressed downstream. Streamflow measurement teams were dispatched to gaging stations downstream of the hardest hit flood areas to obtain direct current meter measurements as the flood peak passed. Peak flow as measured at the Tug Fork at Williamson, downstream of the flood damage area, on Monday morning was at less than a 5 year recurrence interval.

No small drainage area gaging stations in the flood area were equipped with telemetry. Field crews were dispatched to inactive gage stations and non-DCP stations such as crest-stage gages to obtain high-water marks to define the areal extent of the flood. Inactive gage stations are seldom visited except at such flood times and it was found that reference marks for levels were no longer available at some stations. Field inspections of peak gage height were made at 21 active and discontinued streamflow gaging stations. High water marks were not apparent at some gaging stations and it was considered that the flood recurrence interval was less than 2-years in such cases. High-water marks obtained at each gaging station were related to the last available stage-discharge rating to determine an estimate of peak discharge.

At gaging stations for which the July 8, 2001 was significantly higher than the previous rating definition, either a conveyance-slope rating extension or indirect discharge measurement was performed. Flagging of high-water marks was a high priority because clearing of debris from the channels was initiated immediately as floodwaters receded. Information on channel sections to be flagged in the event of a flood are maintained as part of the station gage folders to aid personnel inexperienced in indirect measurement techniques. Indirect discharge measurements were run as described in U.S. Geological Survey Techniques of Water-Resources Investigations book 3, chapter A1 "General field and office procedures for indirect discharge measurements." Flood recurrence intervals were determined from station frequencies or regional equations as reported in U.S. Geological Survey Water-Resources Investigations Report 00-4080 "Estimating magnitude and frequency of peak discharges for rural, unregulated, streams in West Virginia." Results of the indirect discharge measurements showed that the flood exceeded the 100-year recurrence interval on the Guyandotte River at Baileysville (drainage area 306 mi^2), and approached the 100-year recurrence interval on the Tug Fork at Welch (174 mi^2).

FEMA Assistance

After an extreme rainfall event producing significant flooding, it is imperative that the Federal Emergency Management Agency (FEMA) quickly obtains data that describes the areal extent and severity of the event to aid in planning for response, recovery, and mitigation efforts. The type of assistance that FEMA can offer to flood victims is often dependent on the recurrence interval of the flood that caused their damage. For example, if the flood was of a high recurrence interval and not likely to reoccur often then clean-up and repair assistance may be all that is warranted, but if the recurrence interval was low and future flooding is likely then other mitigation options such as relocation are considered.

FEMA issued a Mission Assignment to the USGS on July 13, 2001 to collect data for accurate documentation of the magnitude of the flood disaster. A Statement of Work was developed that outlined initial tasks needed by FEMA for rapid response by the USGS. General guidance in the Statement of Work directed that High Water Marks (HWMs) be obtained along streams and rivers that caused flood damages to buildings and infrastructure, and/or experienced record or near record flooding.

A preliminary assessment July 13, 2001 of communities that reported flood damage was conducted by interview with the West Virginia Office of Emergency Services. Field crews were assigned to survey HWMs on streams and rivers in 8 communities. As the extent of flooding became better defined, in consultation with the local FEMA contact, an additional 12 communities were added to the list of those for which documentation of HWMs were needed. High-water marks were surveyed in several communities along streams for which FEMA Flood Insurance Studies were available. By using Flood Insurance Rate Maps, the high-water mark locations were determined in relation to flood profiles in the flood studies. These flood profiles show the theoretical water elevations of the 10, 50, 100, and 500 year flood events. The surveyed high-water marks were plotted on the flood profiles and the recurrence interval of the July 8, 2001 flood was estimated for each surveyed location along channel.

Landslide Evaluation

Major highways were closed for several days because of washouts and mudslides. More than 200 Amtrack passengers were stranded in Charleston because mudslides closed 50 miles of railroad track. CSX Transportation identified 48 locations with either washouts or rock slides.

In response to reports of extensive landslide damage, the Office of Surface Mining and Reclamation in Charleston took USGS scientists and a geomorphologist from the West Virginia Geological and Economic Survey on an aerial tour of the flood area to observe landslide and debris flows activity. Although the tour was limited in areal extent, evidence of landslides and other debris flows were seen in natural areas, along the benches of old contour mines, and on valley fills of active mountaintop removal coal mines. USGS Geologic Discipline landslide researchers were contacted and a second overflight was organized for these experts. A study of landslide potential in parts of West Virginia is under consideration.

The USGS Center for Integration of Natural Disaster Information was contacted to help in obtaining remote sensing imagery of the flood area. Because repair of landslides, especially along roadways, railways, and on active mine sites is begun in earnest shortly after the flood recedes, it is imperative that imagery be captured soon after the flood event.

Only a very sparse network of official National Weather Service raingages was available to provide rainfall rate and volume data to aid in evaluation of flooding and landslides. Radar estimates of storm intensity and totals are available but data accuracy is unknown. Rainfall gages are operated as part of the West Virginia Integrated Flood Warning System and some are even operated at USGS streamflow gaging stations, but gage calibration is not routinely checked. Often, rainfall gages are operated at streamflow gages just as rough indicators of rainfall intensity even though forest canopy or other obstructions may affect the data quality.

Study of Mountaintop-Removal Coal Mining Impacts

At one coal mine, mud and rock from a valley fill slid into a pond and displaced the water into an already-flooded stream. Over about five minutes Sunday afternoon, a "wall of water" swept down Bulgar Hollow in Raleigh County causing extensive property damage (Charleston Gazette, July 10, 2001). No other instances of pond failures were known to have occurred during this flood event, but much speculation was presented in the press that mountaintop-removal coal mining and related timbering may have increased runoff rates. Governor Bob Wise publicly stated that officials need to study whether environmental factors such as mountaintop mining methods or timbering contributed to the flooding.

The USGS, in cooperation with the Office of Surface Mining and Reclamation, has begun a project to compare peak streamflows from mountaintop-removal coal mine areas with flows from unmined areas. Peak flood discharge of six small stream basins in the southern coal fields flood area will be obtained by indirect methods. The stream basins selected are in close proximity to minimize the variability in rainfall rate and volume that may have occurred over the study area. Three of the small basins are undisturbed by coal mining and three contain reclaimed mountaintop-removal coal mines.

Channel Clearing and Dredging

The floodwaters carried massive amounts of debris into the stream channels which blocked many bridges. These debris consisted of a wide variety of materials such as cars, tires, brush, trees, and the remains of many homes and their contents. Recovery efforts focused on bridge and channel clearing both to salvage personal property and to reopen waterways in the event of further flooding. Public perception generally is that additional dredging of natural channels will eliminate potential of future floods. Demands for channel dredging projects have been a common theme in the press and at public meetings both from private citizens and community officials.

Channel dredging, however, may have little impact on reducing flood peaks for major floods and may actually result in greater flood damage because of increased flow velocity. The West Virginia Department of Natural Resources (WVDNR) recently issued a report which is critical of the extensive amount of channel disturbance from these channel dredging projects because of damage to aquatic habitat. In addition, subsequent to the July 8 flood the WVDNR along with the West Virginia Department of Environmental Protection and the West Virginia Soil Conservation Agency developed a pamphlet titled "Stream Restoration After Flooding" which cautions that dredging is seldom the answer to prevent future flooding. A study to evaluate the degree to which flood levels might be reduced by typical channel dredging projects would be useful to regulators in assessment of potential flood-protection benefits versus environmental damage of proposed dredging projects.

Sedimentation

No fluvial sediment sampling was conducted by USGS in connection with the July 8 flood because of restricted access to the flood area and because of the rapid stream elevation rise and recession. Photographs of the floodwaters taken by residents during the flood all showed that the streams were all heavily laden with sediment. Inside of a USGS wire-weight gage box which had been overtopped during the flood a layer of coarse sand was found. This showed that turbulence was so great that even very coarse material was carried throughout the water column. Fine organic sediments were deposited at the edges of flow and inside structures where water movement was slack. According to one flood recovery worker, "It's the black mud people say they can't stand. It smells like rotting fish. It's on everything they own, and it won't wash off" (Charleston Gazette, July 11, 2001).

Water Supply Reliability

Several sewage treatment plants were overwhelmed during the flood and many septic tanks were actually washed into streams as banks were cut by the floodwaters. Water treatment facilities in some areas were unable to use surface water as a source of supply for weeks after the flood because of extreme sediment and bacteria content. The State Department of Health issued boil-water orders for those water systems able to continue in operation. Reliability of surface water for public supply during times of drought or because of contamination is an area of possible future USGS investigation.

SUMMARY

Floods are among West Virginia's most frequent and costly natural hazard in terms of human hardship and economic loss. Two people died in the July 8, 2001 flood in Southern West Virginia, over 1,000 homes were destroyed, many roads and railways were closed by floodwaters or mudslides, and several bridges were washed out. The U.S. Geological Survey helped in recovery efforts by providing information on flood magnitudes and recurrence intervals which was needed for determining the type of Federal flood assistance to make available for flood victims. Flood data were obtained from current and inactive gaging stations, and by surveying high-water marks in flood affected communities. Efforts were made to initiate USGS studies on landslide potential and on possible flood impacts of coal- mining practices. Some possible future investigations related to flooding include evaluation of channel dredging benefits, sediment transport, and surface water supply reliability.

SESSION V

Surficial Processes and Landslides in the Central Appalachians – Late Pleistocene and Holocene
Benjamin Morgan, Ronald Litwin, and Gerald Wieczorek

Integrating Hazards Information into a Web-Based, Near-Real Time, Geospatial Hazards Information System for the Appalachian Region
Harry McWreath and Art Eckerson

The Status of Species and Recovery Programs for Endangered Freshwater Mussels in the Southern Appalachians
Richard J. Neves and Steven A. Ahlstedt

The Life Cycle of Potentially Toxic Trace Elements in Appalachian Basin Coal
M.B. Goldhaber, J.P. Hatch, L. Lee, E.R. Irwin, A. Grosz, J.B. Atkins, D.D. Black, H. Zappia, J.C. Pashin, R.F. Sanzolone, L.F. Ruppert, A. Kolker, R.B. Finkelman, and H.E. Bevans

Naturally Occurring Radionuclides in Ground Water in the Appalachian Physiographic Province: Initial Results of Targeted Reconnaissance Surveys and Application to Regional Assessment
Zoltan Szabo, Michael J. Focazio, James E. Landmeyer, Lisa A. Senior, Joseph D. Ayotte, Vincent T. dePaul, Timothy D. Oden, and Mark D. Kozar

Reconnaissance Investigation of the Uranium-Series Radionuclide Radon-222 in Drinking Water Wells in the South Carolina Piedmont
James E. Landmeyer and Eric J. Reuber

Surficial Processes and Landslides in the Central Appalachians – Late Pleistocene and Holocene

Benjamin Morgan, Ronald Litwin, and Gerald Wieczorek

The Cenozoic and Quaternary history of the Appalachian highlands includes uplift of a passive plate margin and denudation of the landscape. The terrane is mantled by colluvial deposits that preserve much of that history, especially the late Pleistocene and Holocene. Study of these deposits, principally in the Blue Ridge Province of central Virginia, is providing new insight on the rate of development of soil, saprolite and colluvium during periods of extreme climatic variation, the role of periglacial processes during the late Pleistocene in shaping the landscape, the rates of landscape denudation and sediment transport resulting from mass failure of slopes, and the physical conditions required to trigger extreme ground failure events such as catastrophic debris flows. These insights are useful both for understanding the evolution of the Appalachian highlands as an ecosystem and for implications regarding natural hazards within the area.

Sedimentary analysis of small drainage basins in the Madison, Virginia area following an intense storm in 1995 suggests that nearly half of the mechanical, long term denudation within each basin is a result of debris flows. These failures are a major factor in regional denudation, even though ^{14}C data suggest that average recurrences of debris-flow activity within a given area may be as infrequent as 2000 years. Pollen analyses of dated colluvium and drill cores from bogs provide a record of strongly fluctuating climate during the last 35,000 years, a record of climate change that is similar to the pattern seen in ice-core records from Greenland. Rock streams, cambering, patterned ground, tors, slope wash deposits, and isolated, cold weather plant communities corroborate the presence of periodic scattered or pervasive permafrost conditions in the Appalachians during the late Pleistocene.

Catastrophic debris-flow events occur at about 3 to 5 year intervals within the Appalachian highlands. These events are triggered by heavy rain falling at rates of 1 to 4 inches per hour with a duration of several hours. Inventories of extensive debris flows produced by heavy rainfall in Nelson, Albemarle, and Madison Counties in central Virginia are being used to develop models that can predict the failure sites, timing of triggering, and downslope projections of debris flows. Analyses of debris flows and rates of rainfall have been used to develop an algorithm that defines conditions favorable for triggering flows. Analyses of debris-flow deposits containing charcoal fragments permits the calculation of an average recurrence interval for extreme hazardous events in the highlands area. These data – location, conditions, and frequency for debris-flow events – are critical for making recommendations to federal, state, and local officials on susceptibility to landslide hazards.

Integrating Hazards Information into a Web-Based, Near-Real Time, Geospatial Hazards Information System for the Appalachian Region

Harry McWreath and Art Eckerson
USGS Center for Integration of Natural Disaster Information, 570 National Center, Reston, VA 20192

The U.S. Geological Survey (USGS) Center for Integration of Natural Disaster Information (CINDI) is a geospatial research and operational facility that explores methods for collecting, integrating, and communicating information about the risks posed by natural hazards and the effects of natural disasters. The CINDI provides a focal point for the scientific programs of the Bureau and the Department to integrate information and produce derivative products, using geographic information system (GIS) technology to help communicate the potential impact of natural hazards, especially the impact on humans and their environment and infrastructure.

The CINDI is developing plans to provide a Web-based, near-real time geospatial Hazards Information System for the Appalachian region. A prototype GIS database for the Appalachian Region Focus Area has been produced by the CINDI, as described by Herr and others in the workshop poster session. This system will incorporate the base map data layers of the Appalachian GIS; data layers associated with flood and landslide hazards, such as real-time streamgaging stations, land cover, and slopes; and near-real time data on weather conditions (rain, wind), antecedent conditions (recent precipitation), and forecast conditions (predicted rainfall amounts). This Web-based Hazards Information System will be available to the USGS and others who are in an official capacity for planning and preparing for severe weather events, monitoring ongoing events, and providing follow-up evaluation and analysis of past events. Public access to this system will also be incorporated.

In the Appalachian region, natural hazards are defined by the geographic characteristics of the region. The location and extent of the region on the North American continent control the types of hazard events that the region is most likely to experience. For example, disasters from volcanoes and earthquakes have a very low probability, although a devastating earthquake in the region is still a possibility. The principal hazard is severe weather, primarily heavy precipitation and, to a lesser degree, high winds. Proximity to the Atlantic coast exposes the region to tropical storms, such as hurricanes, in the summer and fall, and to extratropical storms, such as northeasters, in the winter and spring. The occurrence, magnitude, and extent of disastrous or damaging effects from severe weather are controlled by the characteristics of the storm system and the geographic characteristics of the region.

The relief, geology, soils, and land cover influence the response of the land surface to heavy precipitation. High relief and narrow valleys, where the urban infrastructure is located, characterize the Appalachian region. Isolated communities and limited transportation routes are prevalent in the region. Flooding and landslides have caused major loss of life and property repeatedly throughout the history of this region.

The Status of Species and Recovery Programs for Endangered Freshwater Mussels in the Southern Appalachians

Richard J. Neves[1] and Steven A. Ahlstedt[2]
[1]Virginia Cooperative Fish and Wildlife Research Unit, U.S. Geological Survey, Virginia Tech, Blacksburg, VA 24061
[2]U.S. Geological Survey, Suite A, 1820 Midpark Drive, Knoxville, TN 37921

ABSTRACT

Freshwater mussels are the most endangered faunal group in the Southern Appalachians, with 45 species on the Endangered Species List from this region. The Tennessee River is the dominant drainage system [in this region], receiving tributaries from seven states and encompassing a watershed of 105,000 km^2. Within this basin are 102 mussel species, including fifteen endemic taxa, thirty endangered or threatened, and nine presumed extinct species. Trends in abundance and distribution of federally listed species continue downward for most species in this and adjacent river systems, with numerous extirpations from major tributaries in the last half century. To implement objectives in recovery plans, Cooperative Research Units in Virginia and Tennessee and the Southeast Aquatic Research Institute, working with the Upper Tennessee River National Water Quality Assessment (NAWQA) Office-Knoxville, have successfully implemented production and culture methods for a suite of species. The Virginia Unit has released nearly 260,000 endangered juveniles since 1998, and the Tennessee Unit continues to perfect hatchery raceway cultures working with surrogate species. Riverine populations are being augmented with juveniles to increase recruitment and expand ranges in rivers critical to the survival of these species. A collaborative effort by federal and state natural resource agencies, universities, and non-governmental organizations is now focused on restoration of keystone rivers and the mussel species sustained therein.

INTRODUCTION

The freshwater mussel fauna (superfamily Unionoidea) of the United States is of world class diversity. Roughly 300 species and subspecies reside principally in streams and rivers from the Mississippi River system to most major river systems in the eastern United States. Regional and historic traits in geology, water chemistry, drainage patterns, and a suite of other factors have resulted in various degrees of endemism within river systems and faunal assemblages. Of the nearly 300 taxa of mussels, 269 species had historic ranges that included rivers in one or more states of the Southeast. Although a plethora of nominal species were described by early naturalists in the 19th and early 20th centuries using limited taxonomic traits, molecular genetics work in the last 20 years has largely confirmed the prodigious diversity of freshwater mussels in this geographic region. The decline in the mussel fauna began essentially in the early twentieth century with the construction of dams, timber harvest, urbanization, and a host of other anthropogenic impacts to the presumed river systems. In addition to extinct species (Table 1) and the 69 species presently listed as endangered or threatened in the United States, a recent status review has identified many more species as imperiled and in need of protection (Williams et al. 1993).

Freshwater mussels are the most endangered faunal group in the southern Appalachians, with 39 extant species listed as endangered or threatened in this region (Table 2) and 6 extinct species, mostly within the upper Tennessee River basin. This basin includes tributaries in seven states and encompasses a watershed of 105,000 km^2. Within this basin are 102 mussel species, including 15 endemic taxa, 30 endangered or threatened, and up to 9 presumed extinct species (Parmalee and Bogan, 1998). Several of the extinct species occurred in the upper Tennessee River and its major tributaries in Alabama and Tennessee (Table 1). As a taxonomic group, the riffleshells (genus

Epioblasma) and the pigtoes (genus Pleurobema) have experienced the greatest rate of extinction, presumably because of their occurrence and distribution in shoals of medium to large rivers that were inundated by reservoirs or destroyed by dredging to promote commercial navigation. These taxa seem particularly sensitive to habitat and water quality degradation, and these species are readily extirpated after anthropogenic disturbance.

Table 1. Species of freshwater mussels presumed extinct in the United States

Scientific Name	Common Name	State(s) of Occurrence
Alasmidonta maccordi Athearn, 1964	Coosa elktoe	AL
A. robusta Clarke, 1981	Carolina elktoe	NC, SC
A. wrightiana (Walker, 1901)	Ochlocknee arc-mussel	FL
Elliptio nigella (Lea, 1852)	winged spike	AL,GA
Epioblasma arcaeformis (Lea, 1831)	sugar spoon	AL, KY, TN
E. biemarginata (Lea, 1857)	angled riffleshell	AL, KY, TN
E. flexuosa (Lea, 1820)	leafshell	AL, KY, TN
E. florentina (Lea, 1857)*	yellow blossom	AL, KY, TN
E. haysiana (Lea, 1833)	acornshell	AL, KY, TN, VA
E. lenior (Lea, 1843)	narrow catspaw	AL, TN
E. lewisii (Walker, 1910)	forkshell	AL, KY, TN
E. metastriata (Conrad, 1838)*	upland combshell	AL, GA, TN
E. othcaloogensis (I. Lea, 1857)*	southern acornshell	AL, GA, TN
E. obliquata obliquata (Rafinesque, 1820)	catspaw	AL, KY, TN
E. personata (Say, 1829)	round combshell	KY
E. propinqua (Lea, 1857)	Tennessee riffleshell	AL, KY, TN
E. sampsonii (Lea, 1861)	wabash riffleshell	KY
E. stewardsoni (Lea, 1852)	Cumberland leafshell	AL, KY, TN
E. torulosa gubernaculum (Reeve, 1865)*	green blossom	TN, VA
E. t. torulosa (Rafinesque, 1820)*	tubercled blossom	AL, KY, TN
E. turgidula (Lea, 1858)*	turgid blossom	AL, AR, TN
Lampsilis binominata Simpson, 1900	lined pocketbook	AL, GA
Medionidus macglameriae van der Schalie, 1939	Tombigbee moccasinshell	AL
Pleurobema aldrichianum (Goodrich, 1831)	plain pigtoe	AL, GA
P. altum (Conrad, 1854)	highnut	AL
P. avellanum Simpson, 1900	hazel pigtoe	AL
P. flavidulum (Lea, 1831)	yellow pigtoe	AL
P. hagleri Frierson, 1906	brown pigtoe	AL
P. hartmanianum (Lea, 1860)	tawny pigtoe	AL,GA
P. johannis (Lea, 1859)	Alabama pigtoe	AL
P. murrayense (Lea, 1868)	Coosa pigtoe	AL, GA, TN
P. nucleopsis (Conrad, 1849)	longnut	AL, GA
P. rubellum (Conrad, 1834)	Warrior pigtoe	AL
P. verum (Lea, 1860)	true pigtoe	AL
Quadrula tuberosa (Lea, 1840)	rough rockshell	TN, VA

Revised from Turgeon and others. (1998)

*Southern Appalachians

Table 2. Occurrence of endangered mussel species in the Southern Appalachians

Species	Stream (State)
Alasmidonta atropurpurea	Big South Fork Cumberland system (TN, KY), Laurel Fork (KY), Marsh Creek (KY), Sinking Creek (KY)
Alasmidonta raveneliana	Little Tennessee (NC), upper Pigeon system (NC), Little River (NC), Tuckasegee (NC), Cheoah (NC), Toe (NC), Cane (NC), Nolichucky (NC,TN)
Cyprogenia stegaria	Clinch (TN, VA), Licking (KY)
Dromus dromas	Clinch (TN, VA), Powell (TN, VA)
Epioblasma brevidens	Clinch (TN, VA), Powell (TN, VA), Big South Fork Cumberland (TN, KY), Buck Creek (KY)
Epioblasma capsaeformis	Clinch (TN, VA), Nolichucky (TN)
Epioblasma obliquata obliquata	Extirpated
Epioblasma penita	Extirpated
Epioblasma florentina walkeri	Big South Fork Cumberland (TN, KY), Hiwassee (TN), Indian Creek (VA), Middle Fork Holston (VA)
Fusconaia cor	Clinch (TN, VA), Powell (TN, VA), Copper Creek (VA), North Fork Holston (TN, VA), Paint Rock (AL)
Fusconaia cuneolus	Clinch (TN, VA), Powell (TN, VA), Copper Creek (VA), North Fork Holston (TN, VA), Possum Creek (VA)
Hemistena lata	Clinch (TN, VA)
Lampsilis abrupta	Clinch (TN), Holston (TN), French Broad (TN), Tennessee (TN)
Lampsilis altilis	Conasauga (TN, GA), Holly Creek (GA), Duck Creek (GA)
Lampsilis perovalis	Black Warrior system (AL)
Lampsilis virescens	Paint Rock (AL), Estill Fork (AL)
Lemiox rimosus	Clinch (TN, VA), Powell (TN, VA)
Leptodea leptodon	Extirpated
Medionidus acutissimus	Conasauga (TN, GA), Holly Creek (GA), Black Warrior system (AL)
Medionidus parvulus	Conasauga (TN, GA), Holly Creek (GA)
Obovaria retusa	Extirpated
Pegias fabula	Clinch (VA), North Fork Holston (VA), Big South Fork Cumberland (TN, KY), Horse Lick Creek (KY), Cane Creek (TN)
Plethobasus cicatricosus	Extirpated
Plethobasus cooperianus	Extirpated
Pleurobema clava	Extirpated
Pleurobema collina	James (WV, VA)
Pleurobema decisum	Conasauga (TN, GA), Coosa (AL)
Pleurobema furvum	Black Warrior system (AL)
Pleurobema georgianum	Conasauga system (TN, GA), Shoal Creek (AL)
Pleurobema gibberum	Collins (TN), Big Hickory Creek (TN), Barren Fork (TN), Cane Creek (TN)
Pleurobema perovatum	Black Warrior system (AL)
Pleurobema plenum	Clinch (TN), Tennessee (TN)
Ptychobranchus greenii	Conasauga (TN, GA), Holly Creek (GA), Black Warrior system (AL)
Quadrula cylindrica strigillata	Clinch (TN, VA), Powell (TN, VA), Indian Creek (VA)
Quadrula intermedia	Powell (TN, VA)
Quadrula sparsa	Powell (TN, VA)
Toxolasma cylindrellus	Paint Rock (AL), Estill Fork (AL), Hurricane Creek (AL), Lick Fork (AL)
Villosa perpurpurea	Clinch (VA), Indian Creek (VA), Copper Creek (VA), Beech Creek (TN), Obed (TN)
Villosa trabalis	Hiwassee (TN), Big South Fork Cumberland (TN, KY), Buck Creek (KY), Laurel Fork Rockcastle (KY), Horse Lick Creek (KY), Sinking Creek (KY)

Most current efforts to propagate and recover endangered mussels are focused on Tennessee River system tributaries in Virginia and Tennessee. In spite of Tennessee Valley Authority dams and water quality degradation in the 20th century, tributaries have been able to sustain a species richness in reaches unaffected by these habitat alterations. The breadth of this recovery goal is huge; of the 102 species recorded historically from the Tennessee River basin, about 50 species occupy the work area in southwest Virginia and eastern Tennessee where most recovery efforts are focused. To complicate recovery of some species, several taxonomic questions await genetic analyses such as species complexes, cryptic species, and the level of intra-specific variation in shell characters. The list of current described and recognized species in Turgeon (1998) will likely change with further evaluation of the genetics and biology of these animals.

The restoration of this fauna is specified in the various recovery plans for the endangered species, and a national strategy for the conservation of native freshwater mussels (NNMCC 1998). The latter document was prepared by a committee established in 1997, consisting of federal, state, and shell industry biologists with responsibilities to manage the mussel resources in key states with commercial or rare species. The goal of this strategy is to conserve our nation's mussel fauna and ensure that the ecological and economic values to society are maintained at a sustainable level, and to prevent the extinction of federally protected species. To implement these documents, research has been ongoing since the late 1970's to study the life history, reproduction, and ecology of those species listed as endangered since 1975. The 23 species on the Endangered Species List in 1975 has now grown to 69 species, with many additional species of concern in need of status evaluation. Research in the 1980's and 1990's provided a wealth of information on population levels, reproductive biology, and some of the factors responsible for population declines. With these studies as a background, new research was initiated in the 1990's to develop techniques and technology to produce, culture, and release juvenile mussels back to source populations.

The methods for production and propagation of juvenile mussels are sufficiently developed now, such that interested biologists at fish hatcheries, research laboratories, academic institutions, or commercial facilities can pursue the culture of resident species. The culture technology and protocols for propagation have been described (O'Beirn and others, 1998, Milam and others, 2000). The methods accommodate juveniles during the initial pedal-feeding stage (Yeager and others, 1994) and their later filter-feeding mode for suspended algae. As with most bivalves, food quantity and quality are critical for good survival and growth of the juveniles. Empirical experiments have determined the cell density and suitable species to include in the algal diet. Geographic location, water resources, and available facilities need to be considered in any propagation plan to achieve success.

Propagation Programs in Appalachia

The Virginia Cooperative Fish and Wildlife Research Unit at Virginia Tech has developed recirculating aquaculture techniques for the propagation of endangered mussels (O'Beirn and others, 1998, Henley and others, 2001). The first release of endangered juvenile mussels (*Epioblasma f. walkeri*) occurred in the Hiwassee River, Tennessee during fall 1997. Indoor recirculating trough systems began to be used in 1998, and a total of 260,000 endangered juvenile mussels of 8 species were produced, cultured, and released into 4 rivers of the Southern Appalachians, Virginia and Tennessee. These juveniles were released principally at sites upstream of extant populations to expand species ranges or at sites to augment reproduction of resident populations. A gathering of mussel biologists from U.S. Fish and Wildlife Service, Tennessee Valley Authority, U.S. Geological Survey, National Park Service, state natural resource agencies, and non-governmental organizations selected release sites based on best available data on water quality, habitat suitability, historic occurrences, species richness of fish assemblages, and health of extant populations (Saylor and others, 1999). An evaluation of survival success for initial releases is planned for summer 2002, based on anticipated growth rates of juveniles, vulnerability to quadrat sampling, and projected dispersal at sites of release. Controlled experiments on survival and growth rates to be anticipated in the rivers were completed in 2000 (Hanlon 2000), using juvenile releases in a hatchery raceway supplied with ambient river water. These releases indicated that a survival rate of 20-40% can be expected after one year.

In addition to the research and propagation work at the Virginia Unit, the State of Virginia is developing mussel propagation capabilities at the Buller Fish Hatchery in Marion, Virginia. Water from the South Fork Holston River is diverted to several concrete raceways with river substratum. Specimens of several endangered species are being held in the raceway to allow spawning and maturation of glochidia, for induced infestation on host fishes at the hatchery and at Virginia Tech. This portion of the hatchery is to be renovated in 2005, to allow greater capabilities for mussel propagation.

The Tennessee Cooperative Fishery Research Unit at Tennessee Tech has been conducting research on the identification of host fishes for a suite of endangered mussel species in eastern Tennessee and, more recently, the suitability of hatchery raceways for grow-out of juvenile mussels. Graduate student projects have been conducted at both state and federal hatcheries for the last three years, to determine survival, growth rate, and substrate effects on production of juveniles. Six common mussel species were reared in the raceways with excellent growth rates. Juveniles, 2-4 years of age, have been released into various rivers to augment natural reproduction. Although no endangered species have yet been reared for release, additional propagation projects with rare species are planned for the next few years.

The field station of the Southeast Aquatic Research Institute, located in Cohutta, Georgia, has ongoing projects with rare mussels and snails in Georgia and Tennessee. In 2000, the facility released nearly 900 juveniles of two endangered species into the Conasauga River, Georgia and Tennessee. Fifty juveniles of a third endangered species were released into Holly Creek, Georgia, in 2001. This field station is only recently established, and is expanding its tank culture systems for greater production of rare mussels and snails in the lower Southern Appalachians.

The federal fish hatchery at White Sulphur Springs, West Virginia, is also involved in mussel culture activities. In the mid-1990's, the hatchery became a temporary refugium for mussel species, salvaged from the Ohio River system, that were infested with zebra mussels (*Dreissena polymorpha*). Beginning in 1998, a cooperative research project with Virginia Tech has been evaluating the suitability of an outdoor California raceway for grow-out of juvenile mussels. A second project began in 2001 to design and test a double pond system at the hatchery for holding adult and juvenile mussels. Water in one filled pond is fertilized to produce planktonic algae, and the water is pumped to an adjacent pond with chambers (6x2x0.2m) constructed of cinderblocks to contain mussels. Water flows over these chambers and is then pumped back to the algae-producing pond. A building for the production of endangered juvenile mussels is scheduled to be built in 2002, of similar design to the one at the Virginia Tech Aquaculture Center. This hatchery will focus on endangered mussel species in the mid-Appalachian region of the Ohio River system.

Other states (North Carolina, Alabama, Ohio) and federal field stations (Warm Springs National Fish Hatchery, Georgia) have expressed interest in developing capabilities for mussel culture or providing funds or in-kind services to promote species recovery within their respective states. In the last two years, a cadre of state and federal biologists have visited the mussel propagation facility at Virginia Tech, to evaluate whether such technology or techniques could be applied to their specific situation. Propagation is now viewed as a reasonable and prudent activity to prevent further extirpations and extinctions, and to expedite the recovery of listed species through establishment of self-sustaining populations. Water quality has improved substantially in many rivers, such that suitable habitat is no longer the limiting factor for recovery.

We are approaching a new era in federal conservation programs, where sportfish hatcheries will diversify their activities to become national conservation centers for a suite of rare freshwater taxa in their geographic area. Remediation of habitat and recovery of fauna will become the battle cry of the new generation of federal fish and wildlife biologists, becoming proactive rather than reactive to the needs of the species. This approaching wave of recovery programs will provide more opportunities for the Biological Resources Division of U.S.G.S. to participate as a partner with the U.S. Fish and Wildlife Service and other agencies in reversing the downward trend in mussel population losses at all spatial scales.

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The Life Cycle of Potentially Toxic Trace Elements in Appalachian Basin Coal

M.B. Goldhaber [1], J.R. Hatch [2], L. Lee [1], E. R. Irwin [3], A. Grosz [4], J.B. Atkins [5], D.D. Black [3], H. Zappia [5], J.C. Pashin [6], R.F. Sanzolone [1], L.F. Ruppert [7], A. Kolker [7], R.B. Finkelman [7], and H.E. Bevans [8]
[1] USGS, MS973, Denver Federal Center, Denver, CO 80225
[2] USGS, MS977, Denver Federal Center, Denver, CO 80225
[3] USGS, 331 Funchess Hall, Auburn University, Auburn, Al 36849-5414
[4] USGS MS 954 National Center, Reston, 20192
[5] USGS 2350 Fairlane Drive, Suite 120, Montgomery, AL 36116
[6] Geological Survey of Alabama, P. O. Box O., Tuscaloosa, AL 35486-9780
[7] USGS, MS956, National Center, Reston, 20192
[8] USGS, 11 Dunbar Street, Charleston, WV 25301

The lifecycle of trace elements in coal consists of processes that lead to enrichment of these elements together with natural and anthropogenic pyrite occurred after considerable burial and coalification. We believe that some Paleozoic strata of the Appalachian Basin were aquifers for westward migrating fluids during a late phase of the Alleghanian orogeny. Coal beds were particularly favorable sites for deposition of arsenic-rich pyrite. Studies of geologic dispersal mechanisms. Our study concerns the distribution and dispersal of potentially toxic trace elements including As, Hg, Se, Mo, Tl, Sb, and Cu in Appalachian and Black Warrior Basin coal.

Although most Appalachian Basin coal is low in potentially toxic elements, a small but significant proportion of coal analyses are elevated in this suite. Whole coal arsenic contents range above 100 ppm in some samples. The host of the toxic elements is the mineral pyrite. Petrographic and geochemical studies indicate that formation of the trace-element rich controls on potentially toxic trace element distribution are ongoing in Alabama, Kentucky, Virginia, and West Virginia.

The presence of elevated contents of potentially toxic elements in coal raises the potential for natural weathering and coal mining to disperse these elements into the environment. We have conducted geochemical study of nearly 3000 stream sediment samples from northern Alabama and about 1000 steam sediments from Kentucky. Stream sediments from the coal mining area of Alabama are elevated in arsenic (generally >12 ppm) compared to adjacent areas (<12 ppm). Trace element enrichment in eastern Kentucky stream sediments is less apparent. Because the host of arsenic in coal is pyrite, pyrite oxidation, producing acid mine drainage (AMD) is the mechanism of arsenic dispersal to the environment. We conducted field studies at six sites in Alabama. The results show that both the coal mine refuse piles that are a major source of the AMD, and adjacent stream sediments are highly enriched in As with up to 500 and 200 ppm As respectively.

Coal utilization may also effect the environment. Atmospheric deposition of sulfuric and nitric acids from fossil fuel combustion has had a demonstrable impact on the geochemistry of land and water in the northeastern United States. However, atmospheric deposition patterns of particulates from coal-fired power plants are less well known. A recent evaluation of stream sediment data indicates that arsenic is enriched in stream sediment in a part of West Virginia with no major natural geologic source of As. This area is adjacent to (east) of the Ohio River, where numerous coal-fired power plants are located. The stream sediment arsenic could have come from coal fly ash. To evaluate this hypothesis, we studied lake-sediment chemistry in radiometrically dated West Virginia cores. A concentration maximum in As, Hg, Zn, and Pb occurs in sediment deposited in 1969, just prior to the clear air act of 1970. Magnetite derived from fly ash (with characteristic morphology and internal textures) shows a striking positive correlation with the trace elements. Studies are ongoing to understand the extent of the coal fly ash distribution in the northern Appalachian Basin.

Naturally Occurring Radionuclides in Ground Water in the Appalachian Physiographic Province: Initial Results of Targeted Reconnaissance Surveys and Application to Regional Assessment

Zoltan Szabo[1], Michael J. Focazio[2], James E. Landmeyer[3], Lisa A. Senior[4], Joseph D. Ayotte[5], Vincent T. dePaul[1], Timothy D. Oden[1], and Mark D. Kozar[6]
U.S. Geological Survey, [1]W. Trenton, N.J.; [2]Reston, Va.; [3]Columbia, S.C.; [4]Malvern, Pa.; [5]Pembroke, N.H., and [6]Charleston, W.V.

Concentrations of uranium (U) and thorium (Th) generally are higher in the bedrock of the Appalachian Physiographic Province than in bedrock in most other parts of the United States. Because this area is not homogeneous geologically, hydrologically, or geochemically, radionuclide distributions in both bedrock and ground water vary widely. Concentrations of naturally occurring radionuclides in ground water have been detected in some parts of the region that are greater than the drinking-water standards (U, 30 $\mu g/L$ (micrograms per liter); sum of radium-226 (Ra-226) and radium-228 (Ra-228), 5 pCi/L (picocuries per liter)) promulgated or proposed in 2000 by the U.S. Environmental Protection Agency. These concentrations have been documented as part of reconnaissance surveys conducted during 1990-2000 by the U.S. Geological Survey (USGS) in cooperation with State and local agencies. These surveys generally targeted areas in which the rock or water was known to contain high concentrations of these constituents. Concentrations tended to be highest in domestic wells that are not subject to Federal regulation and that consequently are not monitored.

Concentrations of U in ground water in many parts of the Appalachian Physiographic Province range as high as 100 $\mu g/L$. Concentrations typically are highest in oxic waters of neutral to alkaline pH. Dissolution of U is limited in most geochemical environments but typically exceeds that of Th, which is relatively insoluble. Some researchers have hypothesized that the observed concentrations of U may be controlled by adsorption and complexation reactions, because 100 $\mu g/L$ is lower than the concentrations indicated by theoretical U-mineral solubility. In some parts of the Appalachian Province, such as northern South Carolina, concentrations of U on the order of 1,000 $\mu g/L$ or more indicate little or no adsorption of U.

The isotopes of Ra form by decay of both U and Th. They are detected most frequently in elevated concentrations in reducing or acidic waters in quartzite, sandstone, shale, and glacial sediment; the greatest concentrations (Ra-226, 41 pCi/L; Ra-228, 180 pCi/L; and Ra-224, 265 pCi/L) were measured in water from an Early Cambrian quartzite in southeastern Pennsylvania. These three isotopes of Ra, as well as lead-210 (maximum concentration 4.14 pCi/L) were detected in 15 samples of water collected from six states in the Appalachian Physiographic Province during the 1998 USGS targeted national reconnaissance survey of selected radionuclides in public ground-water supplies. Concentrations of radon-222 (a progeny of Ra-226) in ground water in the Appalachian Province consistently have been among the highest in the United States.

Retrospective compilation of data from local ground-water-quality surveys in association with detailed mapping of the geochemical properties of the bedrock in the Appalachian Physiographic Province could be a first step in providing the information needed to formulate hypotheses regarding variations in the distribution of radionuclides in ground water and to design additional sampling surveys. Province-scale geochemical models of the controls on the occurrence and distribution of radionuclides developed from such data are needed to facilitate scientifically defensible decision-making with respect to water-resource management in the region.

Reconnaissance Investigation of the Uranium-Series Radionuclide Radon-222 in Drinking Water Wells in the South Carolina Piedmont

James E. Landmeyer and Eric J. Reuber
U.S. Geological Survey, 720 Gracern Road – Suite 129, Columbia, SC 29210

A reconnaissance investigation of concentrations of the uranium-series radionuclide ^{222}Radon (radon) in water from 19 domestic wells in the Piedmont of South Carolina indicated concentrations above the proposed Maximum Contaminant Level (MCL) of 300 picocuries per liter (pCi/L) in all wells sampled; 5 wells had radon concentration that exceeded the 4,000 pCi/L Alternative MCL. These results for the Piedmont are high relative to radon concentrations measured in domestic wells in Coastal Plain aquifers where only 20 wells out of 61 sampled exceeded 300 pCi/L. In the Piedmont, the highest radon concentrations were observed in water from wells located at moderate (hillside) elevations characterized by a shallower depth to water relative to hilltop locations, and in water from wells having shallow producing zones, such as from near-surface fractures and/or residua. Higher radon concentrations also correlate with moderate (but still oxic) concentrations of dissolved oxygen, specific conductance greater than 100 µS/cm, sub-neutral pH, and low (less than 40 mg/L) bicarbonate concentration. These data may indicate that the domestic wells sampled with high radon concentrations are intercepting ground water in predominantly discharge areas that integrate both local and regional ground-water flowpaths. However, the correlation of high radon with increasing specific conductance suggests that longer flowpaths (greater residence time with host rocks for uranium leaching and subsequent radon production) may predominate. Chlorofluorocarbon (CFC)-based apparent recharge dates of the water sampled in these domestic wells indicate recharge occurring between 1960 and 1980, which is consistent with this hypothesis. These preliminary radon and geochemical data suggest the need to more accurately assess the areal and vertical distribution and processes controlling the fate of radon and other naturally occurring uranium-series radionuclides. This is timely in light of the need to understand the implications to human health in this area of South Carolina (and the Southeast) undergoing rapid development with dependence on these aquifers as a source of drinking water.

SESSION VI

Proxy Climate Evidence from Late Pleistocene Deposits in the Blue Ridge of Virginia
Ronald J. Litwin, Benjamin Morgan, Scott Eaton, Gerald Wieczorek, and Joseph P. Smoot

Use of Light Detection and Ranging (LIDAR) Technology for Mapping Hypsography and Hydrology
Vincent Caruso

Appalachian Basin Petroleum Systems
Robert C. Milici, Robert T. Ryder, and Christopher Swezey

Comparison of the Hydrology of Bent Creek and Cullasaja River Watersheds—An Evaluation of the Effects of Mountain Development
Melinda J. Chapman, Charles C. Daniel, III, and William C. Burton

Collaborative Hydrogeologic Studies in the Appalachian Region by the BRASS Project
William C. Burton, J. Wright Horton, Jr., Michael P. Ryan, Herbert A. Pierce, Lawrence J. Drew, David M. Sutphin, and Joseph P. Smoot

Base-Flow Characteristics of Streams in the Valley and Ridge, Blue Ridge, and Piedmont Physiographic Provinces of Virginia and Other Mid-Atlantic States
Donald C. Hayes and David L. Nelms

DISCUSSION SESSION

Geologic Outreach in Public Lands: We Have the Gold, Let's Take it to the Bank
Jack B. Epstein

Proxy Climate Evidence from Late Pleistocene Deposits in the Blue Ridge of Virginia

Ronald J. Litwin[1], Benjamin Morgan[1], Scott Eaton[2], Gerald Wieczorek[1], and Joseph P. Smoot[1]
[1]USGS, MS 926A, Reston, VA 20192
[2]James Madson University, Harrisonburg, VA 22807

In 1995, a severe thunderstorm cell cluster initiated a series of approximately one thousand catastrophic slope failures (debris flows) along the east front of the Blue Ridge Mountains. These debris flows exposed a number of small depositional remnants (SDRs) of sub-formational rank, of alluvial-colluvial origin, and of unknown age. Most of these SDRs were found interbedded with deposits that we interpret as prehistoric debris flows. The abundance of the latter suggests that debris flows may have had a more substantial influence on the erosional history of the Appalachians throughout the Quaternary than commonly is thought.

Our ongoing study has revealed the following. The SDRs range in scale from one to ten meters in thickness and nearly all include a subinterval formed by sheetwash or ponded water. Some SDRs consist largely of angular, stratified colluvium, and show evidence of having been formed by cryogenic processes. Many SDRs include internally chaotic, poorly sorted deposits of matrix-supported, angular, cobble-to-boulder-sized clasts; these suggest a debris-flow origin. AMS ^{14}C analyses indicate that the SDRs range in age from the Late Pleistocene (>50 ka) to the Holocene (<2 ka). Pollen analyses were undertaken for a subset of these outcrops to test the feasibility of using pollen to determine the dominant vegetation, and thus the climate regime, at (or near) the time of deposition. We also used the pollen analyses to test: 1) the timing of climate change along the Blue Ridge, 2) the temporal responsiveness of the regional flora through the Late Pleistocene, 3) climatic preference in the occurrence of the prehistoric debris flows versus other processes, 4) the temperature variability along the Blue Ridge through the Late Pleistocene, and 5) similarity of Appalachian climate change patterns to patterns in other terrestrial long climate records.

The combined AMS ^{14}C, pollen, and sedimentologic evidence suggests the following:
1) Although these deposits most frequently are mapped as Quaternary alluvium or Quaternary colluvium, SDRs exhibit marked variability in age and depositional character;
2) Pollen analyses of SDRs frequently are successful, and permit characterization of regional flora, proxy temperature, and fire history where pollen productivity is sufficient;
3) Time-sequencing of the pollen results from geographically-clustered, but discrete, outcrops enables construction of a regional composite climate history record for the Late Pleistocene of the Appalachians, an area for which long climate records are sparse;
4) The construction of a composite climate history record enables robust testing against other terrestrial long climate records.

Use of Light Detection and Ranging (LIDAR) Technology for Mapping Hypsography and Hydrology

Vincent Caruso
U.S. Geological Survey, 521 National Center, Reston, VA 20192

In September 2000, the Department of the Interior and the USGS were among several other agency signatories to a historic agreement designating North Carolina as the first Cooperating Technical State (CTS) in the Nation. This agreement delegates the responsibility for developing digital flood insurance rate maps (DFIRM's) to the State. As a result, the USGS has been working with the State in technical review and coordination activities related to this effort. The State of North Carolina is collecting Light Detection and Ranging (LIDAR) data for use in developing DFIRM's for the entire State.

The USGS has been involved for the past few years in evaluating LIDAR technology and has developed new techniques for using LIDAR data to depict subtle changes in extremely flat coastal terrain as well as more extreme changes in upland areas that are steeper with more varied topographic relief. Because LIDAR data can depict highly detailed features of the Earth's surface, the potential exists to portray hydrography in unique ways. The LIDAR was used to capture very small features, such as narrow ditches and potential areas where ponding of water might take place, and thus depict the Earth's surface more as an image than as an elevation model. Therefore, LIDAR data was used to interpret drainage patterns, in addition to serving as the more traditional elevation reference model. As a result, a very detailed drainage network, highly representative of all actual water features, was produced.

This research was successful in deriving more comprehensive drainage networks from the new LIDAR data and able to combine the new networks with existing sources of hydrography and imagery. Innovative types of graphics and digital files were generated to detect and describe the terrain and drainage. It was observed that the LIDAR has very distinct signatures for both coastal and upland watersheds. For example, in low-relief coastal areas the topographic gradients can be very gentle. Using image-enhancement extraction techniques to isolate signatures and subtle variations in the grain of the topographic surface portrayed the associated landforms. ESRI spatial analyst was also key in extracting intermittent, perennial and flood plain drainage characteristics. The combination of LIDAR derived contours and including the use of the USGS DOQ as a visual base layer proved to be invaluable. These processes required high-resolution, centimeter-level measurements of topography that only LIDAR can supply. From these LIDAR data a comprehensive set of derivative graphics and digital files were extracted.

This technology is not restricted to just terrain common to North Carolina. It can be used whenever LIDAR data is acquired, in virtually any region. These techniques are particularly useful, in combination with limited ground truth. Typically, intermittent and perennial drainage can be inventoried and classified. Inaccurate topographic data that exist from older source maps may be updated with the new LIDAR data. Linkage can be made to national hydro database data sets by developing hyper links to the raster and vector data overlays developed with this technique. Invariably, previously undiscovered geologic features and structures are identified and studied. Effects of human induced changes on the topography can also be inventoried and updated. More accurate land use and zoning maps can be generated from the LIDAR using these techniques. For example, a comprehensive flood plan analysis is one product, which is typically produced.

Appalachian Basin Petroleum Systems

Robert C. Milici, Robert T. Ryder, and Christopher Swezey
U.S. Geological Survey, Reston, VA 20192

INTRODUCTION

The Eastern Region oil and gas assessment team is currently assessing the technically recoverable undiscovered oil and gas resources of the northern and central parts of the Paleozoic Appalachian basin under the National Oil and Gas Assessment Project. In general, the hydrocarbon-bearing part of the basin extends from the Champlain Valley along the eastern side of the Adirondack Mountains in New York and Vermont to the Gulf Coastal Plain in Alabama. The assessment areas of the Appalachian basin include the Dunkard basin in Pennsylvania, Maryland, Ohio, and northern West Virginia, the Pocahontas basin in southern West Virginia, eastern Kentucky, Virginia, and northeastern Tennessee, and the Warrior basin in Alabama and Mississippi. Central Region personnel are assessing the hydrocarbon resources of the Warrior basin.

Although we are assessing selected conventional and continuous (unconventional) accumulations within the entire Paleozoic section in the central and northern part of the Appalachian basin, our assessment of is focused on the accumulations that have the greatest potential, mainly the continuous accumulations in the basin. The assessment is based upon geologically defined Petroleum Systems and their components, source beds, reservoirs, and traps. An understanding of the formation, quality, and thermal maturation of source rocks, the generation and migration of hydrocarbons, the formation of reservoirs, traps, and seals, and their interrelationships in space and time is essential to the assessment effort and must be developed in the context of the tectonic, climatic, and eustatic history of the region. We have defined four major petroleum systems in the Appalachian basin, (1) those related to deep Cambrian source beds in the Rome trough, (2) to the early Taconic Utica/Antes shales of Middle Ordovician age (Ryder and others, 1998), (3) to the Devonian black shales of the Catskill delta, and (4) to the Pennsylvanian coal beds of the Appalachian basin. Much of the continuous gas accumulations in basin-center Silurian sandstones have been derived from Utica/Antes source rocks. Black Devonian shales serve as source rocks and seals for conventional and basin-center accumulations in Devonian and Mississippian sandstones. Autogenic Devonian shales serve both as sources and reservoirs for the continuous accumulations of hydrocarbons they contain. Similarly, coalbed methane is generated and produced from its source rock, coal.

The products generated in the assessment process are digital maps of assessment units (GIS) for each of the petroleum systems, which include regional geologic structural elements, organic geochemistry and thermal maturation data, and illustrate pods of mature source rock, the minimum and maximum extent of the petroleum systems, and the location and distribution of reservoirs, pools, wells, and fields.

GEOLOGY

Appalachian petroleum systems developed under tectonic conditions that began in the Late Proterozoic with regional extension and thinning of continental crust during the opening of the Iapetus Ocean and ended 320 million years later with continental collision and crustal thickening during the Alleghanian orogeny. Much of the Paleozoic sedimentary fill of the Appalachian basin was deposited in this area underlain by thinned, transitional crust. The sedimentary deposits and petroleum geology of the basin reflect the interplay between the eustatic, climatic, and tectonic processes that controlled the development of source rocks, reservoirs, traps, and seals as well as thermal maturation, hydrocarbon generation, and migration pathways. Superimposed upon these rock-forming processes are the effects of organic evolution on the types and abundance of organic material available to Paleozoic depositional systems.

The number and quality of petroleum systems is determined primarily by the thickness and organic richness of thermally mature source rocks. Major Appalachian systems are sourced from Devonian shale that was deposited in foreland and intrashelf basins. Regionally interbedded Devonian shale and siltstone formations may reflect climate and/or eustatic sea level changes. Ordovician shale that occurs widespread within an intrashelf basin is the primary source rock for hydrocarbons in Cambrian sandstones and Ordovician limestones, and in the large continuous gas accumulations in Lower Silurian sandstones. Thick Ordovician shale deposited in rapidly subsiding foreland basins probably had good source-rock quality and apparently released hydrocarbons during the Devonian. Marginal conditions for source rocks occurred within Cambrian rift basins, such as the Rome trough (Milici and Ryder, 2000).

RESOURCES

The largest technically recoverable resources of gas remaining in the Appalachian basin are in continuous accumulations within Silurian and Devonian sandstones, Devonian shales, and Pennsylvanian coal beds. In addition, recent discoveries of natural gas in fractured, dolomitized Ordovician limestones in New York and West Virginia, as well as discovery of the Swan Creek field in the fold-and-thrust belt of eastern Tennessee, have demonstrated the potential of large, relatively untested plays in the Appalachian basin.

BASIN-CENTER GAS

Natural gas trapped in low-permeability sandstone reservoirs in the Appalachian basin is an important source of future energy. Most of this energy resource is located in basin-center gas accumulations and adjoining hybrid-conventional oil and gas accumulations. A basin-center gas accumulation (a variety of continuous gas) is a regionally extensive and commonly very thick zone of gas saturation that occurs in low-permeability rocks in the central, deeper part of a sedimentary basin. In comparison, a hybrid-conventional accumulation, which commonly is both oil-and gas-bearing, is located updip from the basin-center gas accumulation and has characteristics of both conventional and continuous accumulations. Typically, gas saturation is so pervasive in the basin-center accumulation that most wells drilled into it are productive. However, the yields are highly variable and range from high-volume wells (production "sweet spots") to very-low-volume, noncommercial wells.

Lower Silurian (Taconic molasse) and Upper Devonian (Acadian flysch) sandstones constitute the more important basin-center gas accumulations in the basin. The Lower Silurian sandstone gas accumulation is charged by an Ordovician black shale source rock (Utica/Antes petroleum system), whereas the Upper Devonian accumulation is charged by several Upper Devonian black shale source rocks (Devonian Shale petroleum system). The potential for basin-center gas in the Appalachian basin, generally having drilling depths from 5,000 to 8,000+ ft, has been recognized since the early 1980s when exploration was expanded from largely depleted hybrid-conventional accumulations into deeper parts of the basin. Recent studies indicate that the Lower Silurian basin-center gas accumulation is characterized by: a) 5-10% reservoir porosity, b) ≤ 0.1 md reservoir permeability, c) low water saturation, d) a broadly defined updip "water block" trap in the adjoining hybrid-conventional accumulation, and e) abnormally pressured reservoirs (mostly underpressured). Estimates of recoverable undiscovered gas in the Lower Silurian accumulation ("Clinton"/Medina sandstones), at a mean value, range from about 8 to 30 trillion cubic feet of gas (Gautier and others, 1996; McCormac and others, 1996). The Upper Devonian accumulation (Elk, Bradford, Venango sandstones) has an estimated 10 to 14.5 trillion ft^3 of recoverable, undiscovered gas (Gautier and others, 1996; Boswell and others, 1996a,b; Donaldson and others, 1996). Additional gas-bearing low-permeability sandstone reservoirs in the Appalachian basin that may qualify as basin-center accumulations—and thus contain probable undiscovered gas resources—are the Upper Devonian-Lower Mississippian Berea Sandstone and the Lower Mississippian Price (Weir sandstone) and Pocono (Big Injun sandstone) Formations.

DEVONIAN GAS SHALES

In general, the Devonian gas-bearing shales constitute the distal part of the Catskill delta. During the deposition of this delta, which resulted from the Acadian orogeny in the northeastern part of the Appalachian region, thick accumulations of siliciclastic sediment spread westward and southward across the basin. Prodelta black shales, rich in organic material, accumulated under anoxic conditions on the periphery of the delta. This organic material consists of plant-derived kerogen, which is a source of natural gas in the east where the source beds are mature, and oil-prone algal-derived kerogen, which is the source of oil and natural gas in the western part of the basin, where the source rocks are marginally mature to immature and much of the produced gas may be biogenic or has migrated up from deeper, more mature parts of the basin (see Boswell, 1996, deWitt, 1986 and Milici, 1993, 1996 for summaries).

The first well drilled for Devonian shale gas was in Chautauqua County, New York, and since then more than 3 trillion cubic feet of gas have been produced from the shale, primarily from the Big Sandy field in eastern Kentucky. A very large resource remains in an area that extends from western New York to northeastern Tennessee, and gas-in-place estimates range from about 200 to 1860 trillion cubic feet. Cumulative production from individual shale gas wells ranges from about 50 to 900 million cubic feet of gas, commonly over a 20 to 30 year period, and the wells are most productive in eastern Kentucky where the black shale is thickest and thermally mature. For the producing areas that were assessed in the 1995 national oil and gas assessment, USGS estimated that the mean technically recoverable gas resource from Appalachian Devonian shales is about 17.3 trillion cubic feet (Gautier and others, 1996).

COALBED METHANE

Since 1980, coalbed methane (CBM) has been developed as a major gas resource in the Appalachian basin, first in the Warrior basin of Alabama, then in the Pocahontas basin of Virginia, eastern Kentucky, and southern West Virginia, and more recently in the Dunkard basin region of Pennsylvania, northern West Virginia, and Ohio. Alabama is by far the greatest producer, where over 5300 wells have been drilled and have produced 1.2 trillion cubic feet of methane. Virginia has produced about 226 billion cubic feet of methane from over 1500 wells, West Virginia 10.2 billion cubic feet from 149 wells, and Pennsylvania 1.8 billion cubic feet from 61 wells.

In the Appalachian basin, coalbed methane is produced from Pennsylvanian strata in advance of mining as a safety measure, may be produced from fractured rock wastes (gob) after underground mining, and may be produced from unmined or unmineable coal beds. The CBM industry began with the realization that methane vented to the atmosphere in advance of mining gassy coal beds was in reality an economic resource. Once ownership problems were resolved (surface owner vs. mineral owner vs. oil and gas lease holder), thousands of wells were drilled for CBM in Alabama and Virginia. Although gas flow rates and rock pressures are generally low compared to those of conventional wells, CBM drilling costs are relatively low and the wells are relatively long lived. Co-produced waters may be an environmental problem, especially if they are saline, and they are commonly injected into deeper depleted gas reservoirs. In addition, the environmental impact of well completion practices in coal beds that contain potable water is under investigation.

Coalbed methane (CBM) occurs within its own source rock (coal) or may migrate and may be trapped in nearby porous reservoirs. When produced, CBM desorbs from coal macerals into fractures and from there into the wells that were completed in the coalbed. Almost all wells drilled into coal beds produce some gas regardless of geologic structure and the reservoirs are regarded as continuous (unconventional) accumulations. Where water occurs within the coal beds, the gas exhibits little tendency to segregate from formation waters and formation waters must be removed to allow methane to escape from the coal macerals through fractures to the well bore. Coalbed methane fields tend to "grow together" as development progresses, so that fields commonly merge and form continuous accumulations that may persist laterally over several counties.

USGS coal assessment maps serve as excellent exploration guides for coalbed methane. These maps illustrate the outcrop and mined out areas of the coal bed, its thickness (isopach), geologic structure, and depth of the overburden above the coal bed. All of these parameters are essential guides for CBM exploration and may be utilized to develop drilling strategies for future development In addition, these assessment maps serve as a basis for ongoing environmental studies, such as acid mine drainage and deep underground mine pools.

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Comparison of the Hydrology of Bent Creek and Cullasaja River Watersheds – An Evaluation of the Effects of Mountain Development

Melinda J. Chapman[1], Charles C. Daniel, III[1], and William C. Burton[2]
[1] USGS WRD North Carolina District Office, 3916 Sunset Ridge Rd., Raleigh, NC, 27607
[2] USGS GD, 12201 Sunrise Valley Drive, MS 926A, Reston, VA., 20192

The effects of development in a mountainous hydrologic setting are being studied as part of the U.S. Geological Survey's (USGS) ongoing, multiyear Piedmont and Blue Ridge Ground-Water Project in North Carolina. Two watersheds of similar size and bedrock geology are being compared: Bent Creek in Buncombe County and Cullasaja River in Macon County. The effects of human impact on water budgets and water quality are being studied. Because of the growth of recreation, retirement, and second homes in mountain communities in the southeastern United States, this information will be useful in regional management and improving the scientific understanding of environmental changes related to development. USGS scientists in water resources (Raleigh, N.C.) and geologic (Reston, Va.) disciplines, are working with hydrogeologists from the North Carolina Department of Environment and Natural Resources, Division of Water Quality, Groundwater Section, in an effort to study the complex fractured-rock hydrologic system in the two watersheds.

The Bent Creek Research and Demonstration Forest near Asheville, which is managed by the U.S. Forest Service, was selected to represent a relatively undisturbed hydrologic setting. The demonstration forest covers approximately 9.4 square miles (mi^2) and lies almost entirely within the drainage basin of Bent Creek, a tributary to the French Broad River. Except for a paved access road that parallels Bent Creek, a small arboretum, and a few walking trails and isolated buildings, the watershed is almost entirely forested and nearly pristine. A detailed geologic map of the forest and watershed has been made by the North Carolina Geological Survey, and core drilling has begun at three areas along a down-slope transect in the forest in an effort to characterize the local subsurface geology. The installation of six clusters, each having three wells that tap the regolith, transition zone, and bedrock, is planned during the first phase of work. Construction of a real-time gage to measure runoff from the watershed is planned.

The upper Cullasaja River watershed, located in Macon County, North Carolina, represents a rapidly developing watershed, and was selected for comparison to the undeveloped Bent Creek watershed. The study area covers approximately 14.9 mi^2. The southern part of the watershed is occupied by the town of Highlands, currently experiencing rapid growth. Homebuilding has spread from Highlands throughout the watershed, and the number of golf courses and residential developments is increasing. Detailed geologic mapping of this watershed is being conducted by scientists from the Bedrock Regional Aquifer Systematics Study (BRASS) project of the USGS geologic discipline. Mapping the distribution of rock types and fractures characteristics will provide an improved understanding of the ground-water system. The collection of real-time ground-water level data from a well located near Highlands is planned, along with a network of observation wells.

Collaborative Hydrogeologic Studies in the Appalachian Region by the BRASS Project

William C. Burton, J. Wright Horton, Jr., Michael P. Ryan, Herbert A. Pierce, Lawrence J. Drew, David M. Sutphin, and Joseph P. Smoot
U.S. Geological Survey, MS 926A National Center, Reston, VA 20192

The Bedrock Regional Aquifer Systematics Study (BRASS), based in the Eastern Earth Surface Processes Team, Geologic Discipline (GD), performs geologic investigations in the Appalachian Region (Pennsylvania to Alabama) to better understand the geologic controls on ground-water availability and quality in bedrock aquifers. These investigations include geologic mapping, structural analysis of rock fabrics and brittle fractures, statistical and geophysical analyses, and hydrogeologic experiments performed in collaboration with hydrologists in the Water Resources Discipline (WRD) and various state and federal agencies. The goal is to understand the bedrock and surficial geologic parameters that control ground water storage and transport, and to improve the ability of geologists, hydrologists, geophysicists, and geochemists to predict and model the physical and chemical processes affecting ground water. Research collaborators in the Appalachian Region include the WRD districts of Pennsylvania, Maryland, Virginia, North Carolina, and Georgia, the Virginia Division of Mineral Resources, the North Carolina Department of Environment and Natural Resources, and the USDA Agricultural Research Service. Current projects in the Appalachian Region include the following: 1) influence of fracture geometry on flow paths and chemical evolution of ground water in the Valley and Ridge province, Pennsylvania; 2) contaminant migration in tilted and faulted sedimentary rocks of the early Mesozoic Newark basin, New Jersey; 3) geologic influence on directional trends in well yields in the Blue Ridge province of northern Virginia; 4) lithologic and fracture control of ground water flow in the early Mesozoic Culpeper basin, Virginia; 5) relationship of ground water flow and geologic structure in the Piedmont of North Carolina; and 6) comparative hydrogeologic analysis of developed and undeveloped watersheds in the Blue Ridge of North Carolina.

Results to date indicate that detailed knowledge of the geologic framework is an essential first step toward understanding the hydrology of fractured bedrock. In central Pennsylvania, closely-spaced fractures parallel to inclined bedding planes in sedimentary rock exert a strong influence on ground-water flow paths and residence times, which in turn effect ground water chemistry. In northern Virginia, a north-south directional trend in well yields in Precambrian gneiss may reflect the influence of Paleozoic foliation and a swarm of diabase dikes. The regional ground-water flow pattern in the adjacent Culpeper basin is shaped by the complex geometry of diabase intrusions, which act as barriers to flow. In northern Georgia, high yields in municipal wells are controlled by the distribution of fault-bounded lithologic units, which are folded into a broad synform.

Because the integration of detailed geologic investigations into hydrogeologic studies is so fruitful scientifically, the BRASS project is seeking more opportunities for collaborative studies having high transfer value throughout the Appalachian Region.

Base-Flow Characteristics of Streams in the Valley and Ridge, Blue Ridge, and Piedmont Physiographic Provinces of Virginia and Other Mid-Atlantic States

Donald C. Hayes and David L. Nelms

Population growth within the Valley and Ridge, the Blue Ridge, and the Piedmont Physiographic Provinces of Virginia has led to concerns about the allocation of surface-water flow and the increase in demands on the ground-water resources. Various hydrologic studies in Virginia have (1) described the base-flow characteristics of streams, (2) identified regional differences in these flow characteristics, and (3) described, where possible, the potential surface-water and ground-water yields of basins on the basis of the base-flow characteristics. Streamflow data were collected and low-flow characteristics computed (annual minimum average 7-consecutive-day flow for 2-year and 10-year recurrence intervals) for 254 continuous-record streamflow gaging stations and 461 partial-record streamflow gaging stations throughout Virginia. The continuous-record data were analyzed by means of historical mean daily discharge data, and the partial-record data were analyzed by means of correlation of discharge measurements to mean daily discharge data. The State was divided into eight regions on the basis of physiography and geographic grouping of residuals computed in regression analysis.

Additional base-flow characteristics were computed for streams in the Valley and Ridge, the Blue Ridge, and the Piedmont Physiographic Provinces of Virginia as part of the Appalachian Valley and Piedmont Regional Aquifer-System Analysis study. The provinces were separated into five regions: (1) Valley and Ridge, (2) Blue Ridge, (3) Piedmont/Blue Ridge transition, (4) Piedmont northern, and (5) Piedmont southern. Various flow statistics, which represent streamflows predominantly composed of base flow, were determined for 217 continuous-record streamflow-gaging stations and for 192 partial-record streamflow-gaging stations. Variability of base flow was represented by the logarithm of the ratio of the 50-percent exceedance discharge to the 90-percent exceedance discharge on the streamflow duration curve (base-flow variability index). Effective recharge rates also were calculated.

Median values for the various flow statistics range from 0.15 cubic foot per second per square mile for the 90-percent exceedance discharge on the streamflow-duration curve to 0.61 cubic foot per second per square mile for mean base flow. The 50-percent exceedance discharge on the streamflow-duration curve is an excellent estimator of mean base flow for the Piedmont/Blue Ridge transition region and Piedmont southern region, but this value tends to underestimate mean base flow for the remaining regions. The base-flow variability index ranges from 0.07 to 2.27, with a median value of 0.55. Effective recharge rates range from 0.07 to 33.07 inches per year, with a median value of 8.32 inches per year.

Differences in the base-flow characteristics exist between the five regions. The median discharges for the Valley and Ridge, the Blue Ridge, and the Piedmont/Blue Ridge transition regions are higher than those for the Piedmont regions. The flow statistics are consistently higher and the values for base-flow variability are lower for basins within the Piedmont/Blue Ridge transition region relative to those from the other regions, whereas the basins within the Piedmont northern region show the opposite pattern. Results from statistical analysis indicate that the regions can be ranked in terms of base-flow characteristics from highest to lowest as follows: (1) Piedmont/Blue Ridge transition, (2) Valley and Ridge and Blue Ridge, (3) Piedmont southern, and (4) Piedmont northern. The base-flow variability index shows an opposite relation and ranks the regions from lowest to highest in the same order.

Group rankings of the base-flow characteristics were used to designate the potential surface-water yield for the regions. An approach developed for this investigation assigns a rank for potential surface-water yield to a basin according to the quartiles in which the values for the base-flow characteristics are located. Both procedures indicate that the Valley and Ridge, the Blue Ridge, and the Piedmont/Blue Ridge transition regions have moderate-to-high potential surface-water yield, and the Piedmont regions have low-to-moderate potential surface-water yield.

In order to indicate potential ground-water yield from base-flow characteristics, aquifer properties for 51 streamflow-gaging stations with continuous-record streamflow data were determined by methods that use streamflow records and basin characteristics. Areal diffusivity ranged from 17,100 to 88,400 feet squared per day, with a median value of 38,400 feet squared per day. Areal transmissivity ranged from 63 to 830 feet squared per day, with a median value of 270 feet squared per day. Storage coefficients, which were estimated by dividing areal transmissivity by areal diffusivity, ranged from approximately 0.001 to 0.019 (dimensionless), with a median value of 0.007.

The median value for areal diffusivity decreases as potential surface-water yield of the basins increases. Areal transmissivity generally increases as storage coefficient increases; however, basins with low potential surface-water yield generally have high values of areal transmissivity associated with low values of storage coefficient over a narrow range relative to those from basins designated as having moderate-to-high potential surface-water yield. Although the basins with high potential surface-water yield tend to have comparatively lower values for areal transmissivity, storage coefficients generally are large when compared to those from basins with similar values of areal transmissivity but different potential surface-water yield.

Aquifer properties were grouped by potential surface-water yield and were related to hydrogeologic units categorized by large, medium, and small well yields for the Valley and Ridge Physiographic Province and for the Blue Ridge and the Piedmont Physiographic Provinces. Generally, no trend is evident between areal diffusivity and the hydrogeologic units. Some of the high values of areal diffusivity are associated with basins predominantly underlain by hydrogeologic units with small well yields, especially basins with a low potential surface-water yield. Areal transmissivity and storage coefficient tend to decrease, as expected, as more of the basin is underlain by the hydrogeologic unit with small well yields in the Valley and Ridge Physiographic Province. A similar trend is indicated for the hydrogeologic unit with medium well yields in the Blue Ridge and the Piedmont Physiographic Provinces. Areal transmissivity and storage coefficient tend to increase, which is unexpected, as more of the basin is underlain by the hydrogeologic unit with small well yields in the Blue Ridge and the Piedmont Physiographic Provinces. The base-flow characteristics of a basin may provide a relative indication of the potential ground-water yield, but other factors need to be considered, such as geologic structure, lithology, precipitation, relief, and the degree of hydraulic interconnection between the regolith and bedrock.

Baseflow characteristics also were computed for 221 additional continuous-record streamflow gaging stations from North Carolina, Maryland, Delaware, Pennsylvania, and New York as part of the Mid-Atlantic Integrated Assessment study. Regional clusters of the group rankings of the base-flow variability index are evident spatially. Analysis of the data plots suggests that the Piedmont/Blue Ridge transition region extends into central and western North Carolina. Other regional clusters suggested by data analysis are within the Appalachian Plateaus in southwest Virgina and Pennsylvania and Fall Zone areas in eastern Virginia and possibly eastern North Carolina.

Geologic Outreach in Public Lands: We Have the Gold, Let's Take it to the Bank

Jack B. Epstein
U.S. Geological Survey, MS926A, Reston, VA 20192

Communication of geologic information is crucial for informed decisions in making public policy. This is particularly true in managing public lands; in addressing environmental issues, coping with natural hazards, and recommending wise use of our natural and scientific resources. Research on state and federal lands should also be directed to enhance public understanding of our earth systems.

Usable scientific data are required by the National Park Service to carry out its mission of management and interpretation of much of the nation's public lands. The USGS has had a long history of geologic research in the Nation's Parks. In 1994, based on the USGS concern with "total quality management" and recognizing the NPS as a prime customer of our geologic information, both agencies entered into a memorandum-of-understanding in which the USGS would supply earth-science information for selected park lands. The projects were funded through the National Cooperative Geologic Mapping Program in the Geologic Division, so bedrock and surficial geologic maps were to be the prime products to help optimize land-use decision making on NPS lands. NPS personnel ranked approximately 40 geologic project proposals submitted by the national parks. Fourteen projects, distributed nationally, were selected in 1995 that meet the immediate needs of both agencies. Issues related to land management and planning were of prime concern in prioritizing these projects. In 1996 the Geologic Division initiated a "Geologist-in-the-Park Program" which designated a USGS scientist for each park to interpret the geology, to prepare geological information packets, videos, or other outreach materials, and to assist in training park rangers.

Many of the unique attributes of the nation's National Parks are based on geology. Their scenery is the result of many natural processes acting upon the variety of rocks that were formed in diverse environments in the geologic past. Knowledge of the geologic origin of these attributes, training of NPS personnel in their proper interpretation, and communication of this information to the public is an important priority of NPS. A comprehensive geologic information data base of each park is necessary to carry out that park's mission of management and serving the public. The USGS along with the State Geological Surveys are uniquely qualified to contribute to that inventory of park resources. Geologic maps and scientific reports form the basis for a variety of interpretive publications. These include digital data as part of a GIS showing bedrock and surficial geology, resource and hazard potential, trail guides, interpretive leaflets and brochures, and exhibits. Issues addressed include water availability and quality, scientific and cultural resource management, trail and visitor center location, ecosystem characterization, and inventory of paleontologic, geologic, and archaeologic sites. Public educational outreach is a major aspect of this cooperative interagency effort. USGS geologists have developed innovative ways to communicate geologic information and its applicability to environmental issues to park staff through workshops, field trips, and seminars.

Each national park has developed a unique management system. Few parks have geologic expertise (biologists outnumber geologists by more than 20:1). Perception of the usefulness for geologic data is quite variable and park management may be unaware of the value of geologic data. Therefore, in order to propose meaningful tasks, there must be considerable preliminary interaction and evaluation between park officials and USGS scientists. While the perceived (and unperceived) needs for geologic information may be unique for each park, a national perspective within the USGS should be developed. A national project is needed to coordinate the efforts, and to work closely with NPS-Geologic Resources Division (GRD) to ensure coordination of funding, manpower, and data base standards.

National Parks within the Appalachian Highlands are close to large population centers and are heavily visited. The Eastern Earth Surfaces Processes Team has done geologic mapping and concomitant outreach in several parks, including Great Smoky Mountain National Park, Shenandoah National Park, C&O Canal National Historical Park, Great Falls Park, Harpers Ferry National Historical Park, and Delaware Water Gap National Recreation Area.

The Delaware Water Gap National Recreation Area (DEWA), which lies within the heart of the Boston-Washington urban corridor, is the largest National Park facility in the northeastern United States and the ninth most heavily visited NPS facility in the country, attracting about 5 million visitors a year (Great Smoky Mountains NP is third). The efforts to supply earth-science information to DEWA to carry out its management responsibilities include upgrading their inventory data bases, land-use management/planning, training of Park Rangers, aid in trail and exhibit design, involving the park in a GSA symposium and a major Field Conference, informal geologic fireside chats, and potential development of a curriculum-based education program that will meet State and National curriculum standards at the K-6 level. Resulting curricula materials will be included in the park's web site, making it readily accessible to many schools not involved in the project preparation. Based on an extensive mapping program and complete understanding of the geology of the park by the USGS, this task will allow the USGS to help in the primary mission of interpretation and education in the NPS. Geologic resources within the park allow for the following themes to be developed: glaciation, geomorphic development of the Appalachians, origin of waterfalls, rocks and minerals, structure and plate tectonics; fossils, relation of geology to anthropology and historic development of the region.

The results of efforts in DEWA have been only a partial success. Similarly, the total USGS-NPS project, which was divided among the three USGS administrative regions, could have been better. The successes and failures in the three regions were variable. Also, coordination with the Geologic Resources Division of the NPS, whose mission includes protection, preservation, and understanding the geologic resources of the National Park system, could have been better, especially if a more formal liaison had been established. Presently, NPS has liaison personnel in the three USGS regions, but the reverse is not true. This is especially significant because recently some funding has crossed the line from the NPS to the USGS. Finally, there are many ways in which a USGS-multi-disciplinary approach can be made with the National Park Service. For example, BRD's Vegetation Mapping Program in the National Parks could be facilitated with geologic maps that will foster better understanding of the geologic framework of the park.

What might we do?

Geologic maps and research articles by themselves may have little meaning to non-geologists. It is crucial that we develop a methodology to interpret these products for the variety of land-use issues in the National Park service. Whereas the present efforts in the "National Parks Project" in the USGS is directed mainly to geologic mapping and related scientific research, we have come to realize that without taking the next step, much of the valuable information gleaned from this research will not be useful. The USGS has built a huge geologic data base, both published and in the corporate memory of its geologists. Much of that information is going unused. It is the gold needed by the Park Service. Let's discuss how to take it to the bank.

A three-component approach is suggested: **research, interpretation, resource management**.

Research: Without the basic science, including mapping, the other two components would not have a supportive base. This includes completion of geologic mapping in individual parks where necessary and at the proper scale, and basic research in structure, stratigraphy, paleontology, surficial processes, material resources, and hazards. Scientific publications would be the result of this category. The knowledge gained by this research should be incorporated in park interpretation programs and decisions of resource management. Much of this effort is presently underway. Unfortunately, it is the main basis for promotion in our personnel evaluation system. Because of this, the two following components may be demeaned.

Interpretation: The data developed by the scientific research needs to be reformatted and made understandable to NPS personnel and the general public. The products may include interpretive maps, manuals, brochures, field guides, trail and roadside exhibits, visitor center displays, and others. Keith High, former computer specialist at DEWA once said, "now that I have geologic maps in my GIS data base, what can I do with them?" As scientists, we are steeped in jargon, an obscure geologic vocabulary. We try to cram as much information into the smallest space (abstracts), be as efficient with words and graphics as possible (reports, maps), or give the impression of great knowledge (oral presentation). Our colleagues may understand us (sometimes they don't), but this obscure vocabulary may exclude our non-scientist audience, the planners, managers, politicians, common folk, etc. This language barrier may effectively keep these people from understanding the value of our science. Again, we have the "gold"; let's make sure we convert it into currency that has not been devalued by our jargon.

Resource and Land Use Management: Geologic information, both scientific reports and interpretive products, needs to be useful to NPS in their resource Management Plans. This includes aid in inventories and monitoring of their geologic resources, including paleontologic sites, type or reference stratigraphic sections, and unique geologic features such as tectonic and sedimentary structures, glacial features, and sites uniquely displaying geologic processes. An understanding of potential hazards, especially landslides and karst subsidence in the Appalachian Highlands, as well as an understanding of the land-use characteristics of surficial materials, is critical for proper land use management in the parks. USGS geologists could coordinate with NPS personnel, as appropriate, to help update a park's resource management plan and help implement actions and studies that the plan advocates. This includes applying existing and updated theories of geologic principles to understand the park's geologic resources, incorporating this knowledge into understanding ecosystem attributes, and amelioration of human-caused disturbances, especially related to watershed contamination. Additionally, we can coordinate with NPS in their "Geologists in the Park Program" by aiding in selection of individuals and, where requested by the individual park, guide and mentor those individuals.

In conclusion, the NPS has indicated in their web site that their scientific needs include fundamental research, synthesis of geologic literature, mapping, inventory, site evaluation, developing brochures and informative media presentations, and educating staff. The purpose of the USGS program should be to help NPS management understand, manage, and interpret their geologic resources.

Some questions and thoughts for consideration:

1. Without going deeply into the debate concerning basic research vs. applied research, how much of our future research should be directed toward preparing information that is truly useful to our customers, the NPS being an example?

2. To what extend does the present funding criteria within GD encourage or discourage the application of our geologic research to the management needs in public lands?

3. Have we been seamless or *seamfull*? There are many examples of projects within a Discipline that is unknown to workers in other Disciplines. How can we improve this situation?

4. Can we better integrate our activities with other federal agencies, especially the Park Service?

POSTER PRESENTATIONS

Digital Water Resources Data for Georgia
S. Jack Alhadeff, Daniel V. Alhadeff, Brian E. McCallum, and Mark N. Landers

Using the Digital Environmental Atlas of Georgia for Natural Resource Investigations
S. Jack Alhadeff, Jonathan W. Musser, and Thomas R. Dyar

Characterizing the Fractured Crystalline-Bedrock Aquifers of North Carolina – A Federal and State Cooperative Study
Melinda J. Chapman, Charles C. Daniel, III, J. Wright Horton, Jr., and William C. Burton

Arsenic is Ubiquitous but not Elevated in Abandoned Coal-Mine Discharges in Pennsylvania
C.A. Cravotta, III, K.J. Breen, and R. Seal

Ground-Water Exploration and Development in Igneous and Metamorphic Rocks:
Part I – Influencing Factors and Considerations
Thomas J. Crawford and Randy L. Kath

Cytology of the Pallid Sturgeon Sperm Cell
Martin N. DiLauro, Wayne S. Kaboord, and Herbert Bollig

Cytology of the Lake Sturgeon Sperm Cell
Martin N. DiLauro, Wayne S. Kaboord, and Kofi Fynn-Aikins

Geochemical, Mineralogical, and Environmental Characteristics of Metamorphosed Black Shales of the Central Appalachians, with Comparisons to Metalliferous Shales of the Northern Appalachians
Nora Foley, Scott Southworth, Arthur P. Schultz, Robert A. Ayuso, Gilpin R. Robinson, and Robert R. Seal

Indicator-Bacteria Concentrations in a River with Designated Uses of Drinking Water and Recreation, Metropolitan Atlanta, Georgia, 1999-2000 – an Example from a Headwater Piedmont Watershed
Elizabeth A. Frick and M. Brian Gregory

A Low-Cost and Effective Method to Help Characterize Flow in Piedmont Fractured Crystalline Rock, Marietta, Georgia
Gerard J. Gonthier

Abstract not available—Appalachian Region 1:2,500,000-scale United States Geological Survey Map and Database
Anthony Herr, Jr., Arthur Eckerson, and David Dee

Abstract not available—Trends in Water Use and the Implications for Water-Supply Conflicts in the Appalachian Region
Susan Hutson

Water Quality of Springs in Carbonate Rock in the Upper Tennessee River Basin, 1997
Gregory C. Johnson

Landscape Influences on Ambystomatid Salamander Populations in the Delaware Water Gap National Recreation Area
J.T. Julian, C.D. Snyder, J.A. Young, T.L. King, and D.P. Lemarié

Amphibian Research and Monitoring in the Appalachian Region
Robin E. Jung, Karen C. Rice, C. Kenneth Dodd, Jr., and W. Brian Hughes

Ground-Water Exploration and Development in Igneous and Metamorphic Rocks:
Part II – Case Histories from the Southeastern Piedmont/Blue Ridge Province
Randy L. Kath, Thomas J. Crawford, and Lester J. Williams

Monitoring Coliform Bacteria in a Piedmont River Arising from the Appalachian Region of Northern Georgia
Stephen J. Lawrence

Terrestrial Carbon Sequestration – A Potential Land-Use Management for Mitigation of Greenhouse Gas Emissions
H.W. Markewich and G.R. Buell

Comparison of Bacterial Source-Tracking Methods and Investigation of the Sources of Fecal Contamination to Ground Water in Berkeley County, West Virginia
Melvin Mathes and Don Stoeckel

Forest Change Within Shenandoah National Park
David D. Morton, John A. Young, and Dan Hurlbert

Effect of Clearcutting on Nitrogen Export from a Watershed in the Catskill Mountains, New York
Peter S. Murdoch and Douglas A. Burns

Paleozoic through Cenozoic Uplift, Erosion, Stream Capture, and Deposition History in the Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain Provinces of Tennessee, North Carolina, Virginia, Maryland, and District of Columbia
C.W. Naeser, N.D. Naeser, M.J. Kunk, B.A. Morgan, III, A.P. Schultz, C.S. Southworth, and R.E. Weems

Concentration-Discharge Patterns in Acid-Neutralizing Capacity During Stormflow in Three Small, Forested Catchments in Shenandoah National Park, Virginia
Karen C. Rice, Jeffrey G. Chanat, George M. Hornberger, and James R. Webb

GEODE—An Interactive Data Retrieval, Display, and Analysis Internet Application
A. Schultz, R. Wardwell, and M. Levine

Landscape Influences on Aquatic Assemblages: Fish, Bugs, and Salamanders
C.D. Snyder, J.A. Young, D.P. Lemarié, R.F. Villella, D.R. Smith, and Z.B. Johnson

Hydrologic Hazards and Streamgaging Needs in the Appalachian Mountain Region
Timothy C. Stamey and Keith McFadden

Research on Freshwater Mussels (Bivalvia: Unionidae) in Appalachian Streams
Rita F. Villella, David R. Smith, Tim L. King, and David P. Lemarié

Sample Design for Estimating Distribution and Abundance of Freshwater Mussels (Bivalvia: Unionidae) Within a Watershed
Rita F. Villella, David R. Smith, and David P. Lemarié

Abundance and Movements of American Eels near Millville Dam, Shenandoah River, West Virginia
Stuart A. Welsh and Steve D. Hammond

The Role of Two-Dimensional Direct-Current Resistivity (2D DC-Resistivity) Profiling in a Water-Resource Investigation: Application to Ground Water Exploration and Development in Igneous and Metamorphic Rocks of the Georgia Piedmont/Blue Ridge
Lester J. Williams

Assessing Vegetation Community Composition in Relation to Environmental Gradients in Shenandoah National Park, Virginia
John Young, Dean Walton, Gary Fleming, and Dave Morton

Abstract not available—Activities and Future Directions of the National Water-Quality Assessment Program in the Appalachian Region
Michael Yurewicz and Jim Smoot

Digital Water Resources Data for Georgia

S. Jack Alhadeff[1], Daniel V. Alhadeff[2], Brian E. McCallum[2], and Mark N. Landers[2]
[1] United States Geological Survey, Georgia Tech College of Architecture, GIS Center, 276 Fifth Street NW, Atlanta, Georgia 30332-0695
[2] United States Geological Survey, Peachtree Business Center, Suite 130, 3039 Amwiler Road, Atlanta, Georgia 30360

The U.S. Geological Survey (USGS), Georgia District, in cooperation with federal, state, and local agencies has revised the Georgia Surface-Water Annual Data Report, previously published as a paper report, to a new, more informative and functional format on CD-ROM. The new format is based on a geographic information system (GIS) user interface that allows the user to view map locations of the hydrologic monitoring stations and networks within their respective basins.

Several methods are provided for users to easily search for and retrieve data on stations. Graphical summaries of the current water year and selected historical data illustrate seasonal and annual stream characteristics. Users can view or print out site information and data tables in the traditional paper report format, or download data for their use with other applications.

This digital data report includes the annual surface water data that has historically been published as a paper report. The CD-ROM, Georgia Surface-Water Annual Data Report, adds more functionality for the user, including graphical views of the data, digital files of data sets from each gaging station, a site location map, and photography at selected station locations. These options for a streamflow (discharge) station are shown in figure 1. The CD-ROM also contains user-friendly help and examples.

The first page of the station summary (figure 2) gives the user a graphical summary of the selected streamflow station. An annual hydrograph, a graph of historic monthly statistics (maximum, minimum and mean), a graph of annual mean streamflow, a graph of annual peakflows, a site location map, and a photograph are included for most sites. The summary file is comprised of a station manuscript, which contains descriptive information, period of record, location, historical extremes, record accuracy and comments, as well as annual data tables of daily records, monthly statistics, and period-of-record statistics.

The data sets contained on this CD-ROM include the stage and streamflow from all continuous and non-continuous gaging stations for the 1999 water year. All continuous water-quality monitoring data sets also are included in this release. Discrete water-quality sampling sites and continuous ground-water-level monitoring wells are shown as network data layers; however no measurement data are included on this CD-ROM.

The year 2000 report will contain all USGS water resources data for Georgia, including water quality and ground-water measurements. Delineations of the watersheds at selected surface-water stations will be included. Also, several useful tools will be added, including searching for sites at a specified radius, a measurement tool, and the display of latitude-longitude at any point on the GIS user interface.

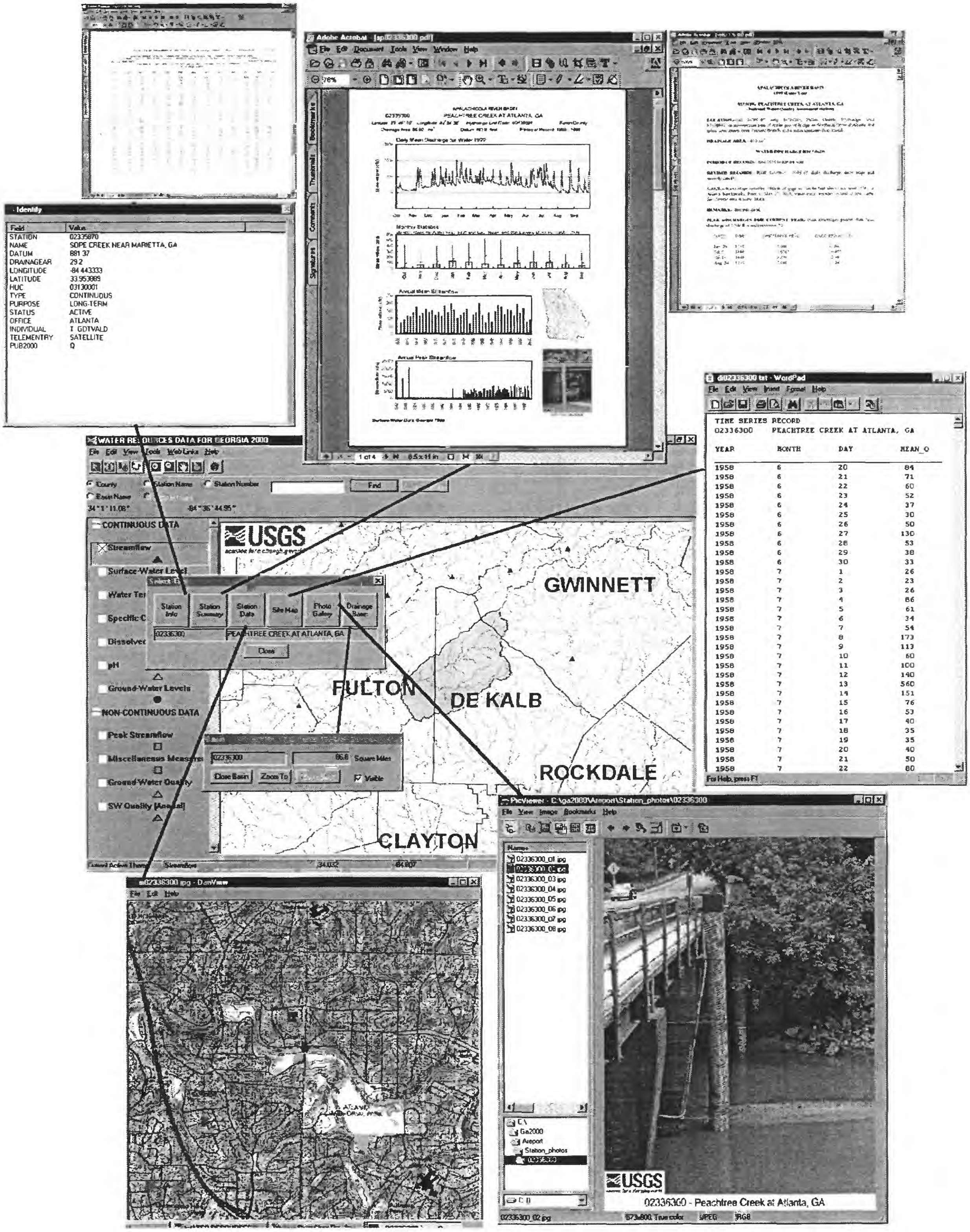


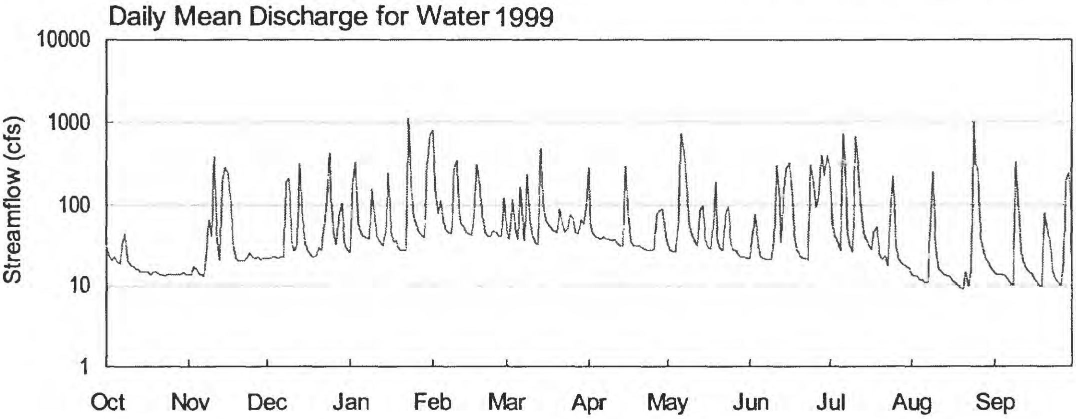
Figure 1. Options for a selected streamflow (discharge) station.

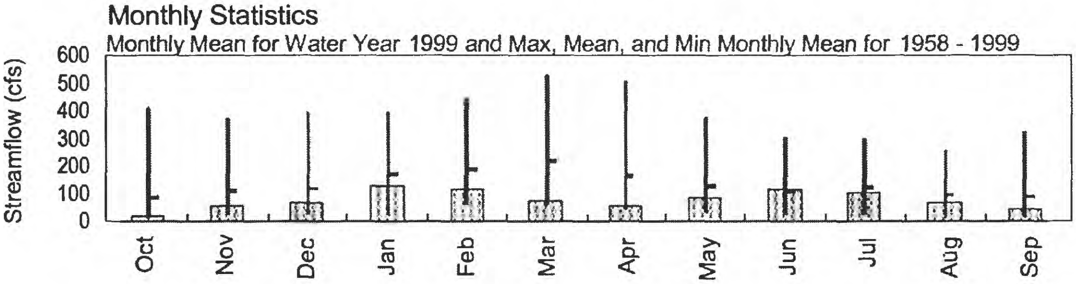
APALACHICOLA RIVER BASIN

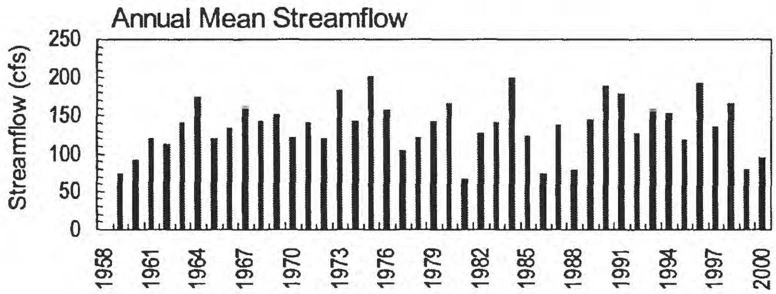
02336300 PEACHTREE CREEK AT ATLANTA, GA.

Latitude: 33°49' 10" Longitude: 84°24 28" Hydrologic Unit Code: 03130001 Fulton County

Drainage Area: 86.80 mi² Datum: 763.9 feet Period of Record: 1958 - 1999







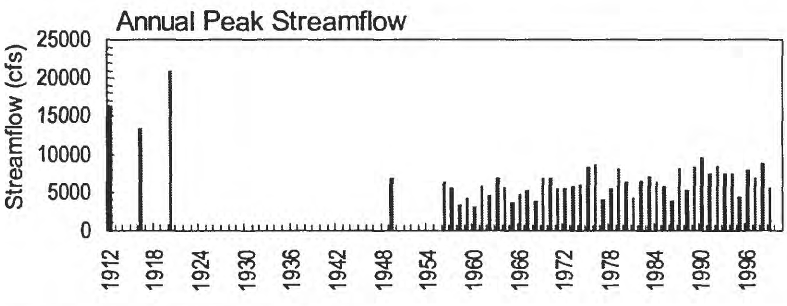


Figure 2. Graphical summary page for Peachtree Creek at Atlanta.

Using the Digital Environmental Atlas of Georgia for Natural Resource Investigations

S. Jack Alhadeff, Jonathan W. Musser, and Thomas R. Dyar
United States Geological Survey, Georgia Tech College of Architecture, GIS Center, 276 Fifth Street N.W., Atlanta, Georgia 30332-0695

ABSTRACT

The U.S. Geological Survey (USGS) and Georgia Department of Natural Resources, Environmental Protection Division, Georgia Geologic Survey recently released (2000, updated and re-released in 2001) a two-volume Compact Disc (CD) set entitled "Digital Environmental Atlas of Georgia" (Atlas) containing computer readable data sets for geographic information systems (GIS). The Atlas not only provides a wide range of traditional maps, but also enables users to experiment with their own individually created maps through personal-computer-based GIS software included on the CDs. The information on the CD set will help Georgia's students learn more about their state and will be useful to businesses and various local, State and Federal agencies.

The CDs contain 38 digital map data sets covering the State of Georgia that are useful to the general public, private industry, schools, and government agencies. The data sets include: Towns and Cities, Public Lands, State Parks, Trails and Greenways, County Boundaries, Geographic Names, Hydrologic Units, Shorelines, Soils, Major Roads, Public Airports, River Reach - Major Streams, Roads, Ground-Water Site Inventory, Hydrography, 7.5-Minute Topographic Quadrangle Index, Surface-Water Monitoring Stations, Elevation Contours, 1:250,000-scale Digital Elevation Model, 1:100,000-scale Digital Raster Graphic, 1:250,000-scale Digital Raster Graphic, 1:500,000-scale Digital Raster Graphic, Land Cover, Land Use, Pipelines, Transmission Lines and Miscellaneous Transportation, Railroads, River Corridors with Mean-Annual Streamflow Greater than Four Hundred Cubic Feet Per Second, 1:250,000-scale Slope, National Forests, Physiographic Provinces, Surficial Geology, Ground-Water Pollution Susceptibility, Most Significant Ground-Water Recharge Areas, and the Georgia Department of Transportation State Highway Map.

ArcExplorer® Version 1.1 software, by Environmental Systems Research Institute, Inc.[2], is included on the CDs. ArcExplorer allows the user to display combinations of data sets and attributes using selected colors and patterns. Spatial and logical queries also can be performed to locate selected sets of attributes. ArcExplorer gives the user the ability to perform the following spatial functions using the data sets on the CDs:

- Overlay multiple data sets
- Identify data set features
- Find and locate features using data set attributes
- Query the data sets using Boolean logic
- Create tables of selected data set features
- Create custom maps for use in reports
- Measure areas and distances within data sets

Three examples of these capabilities are illustrated below. The included ArcExplorer GIS interface depicting user-selected spatial data is shown in figure 1. The results from a query of residential landuse by county (DeKalb) is shown in figure 2. Both tabular and graphical results are displayed. A schist mica/gniess/amphibolite geologic formation in the vicinity of Stone Mountain, over a 1:100,000-Scale topographic map of the area is shown in figure 3. Additional examples depicting a variety of uses for the data covering the functionalities listed above are included on the CD.

Additional GIS information for Georgia may be accessed through the USGS website for Georgia at http://ga.water.usgs.gov or on the Georgia Department of Natural Resources website at http://www.dnr.state.ga.us. Similar information products are being made available by the Georgia GIS Clearinghouse (with active participation from a number of Federal and State and local agencies), website at http://www.gis.state.ga.us.

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[2] Any use of trade names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government

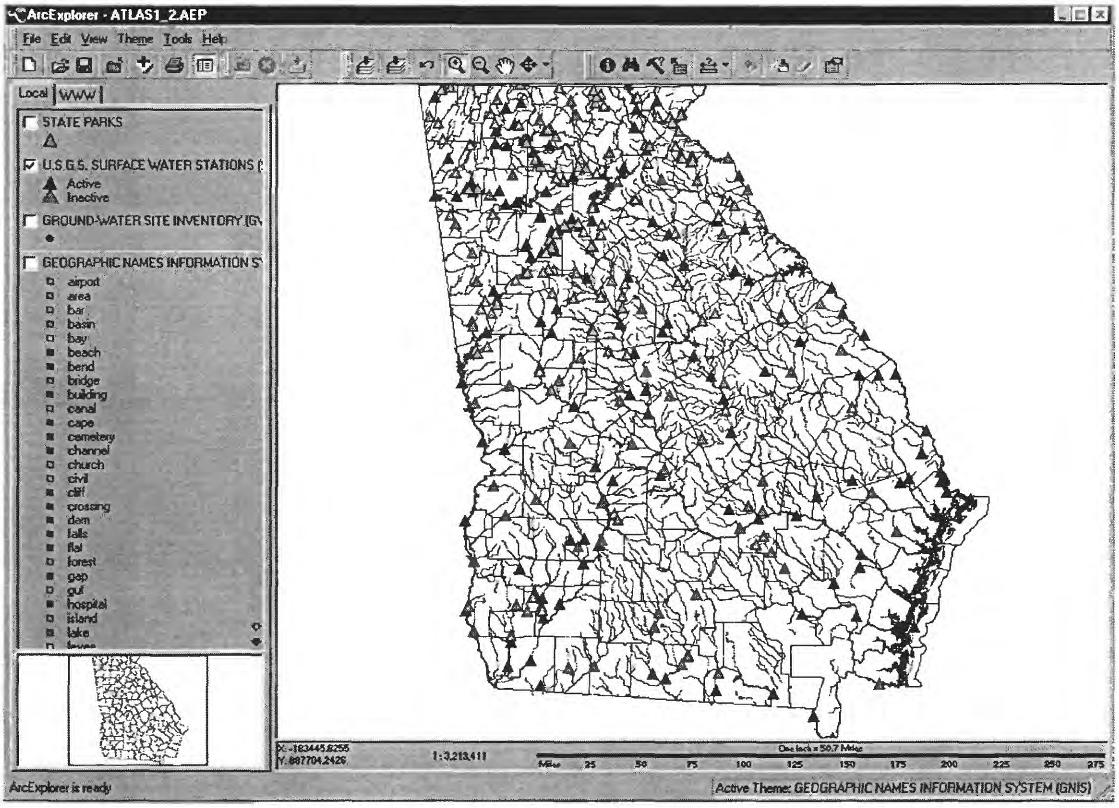

Figure 1. ArcExplorer GIS interface to the Digital Environmental Atlas of Georgia.

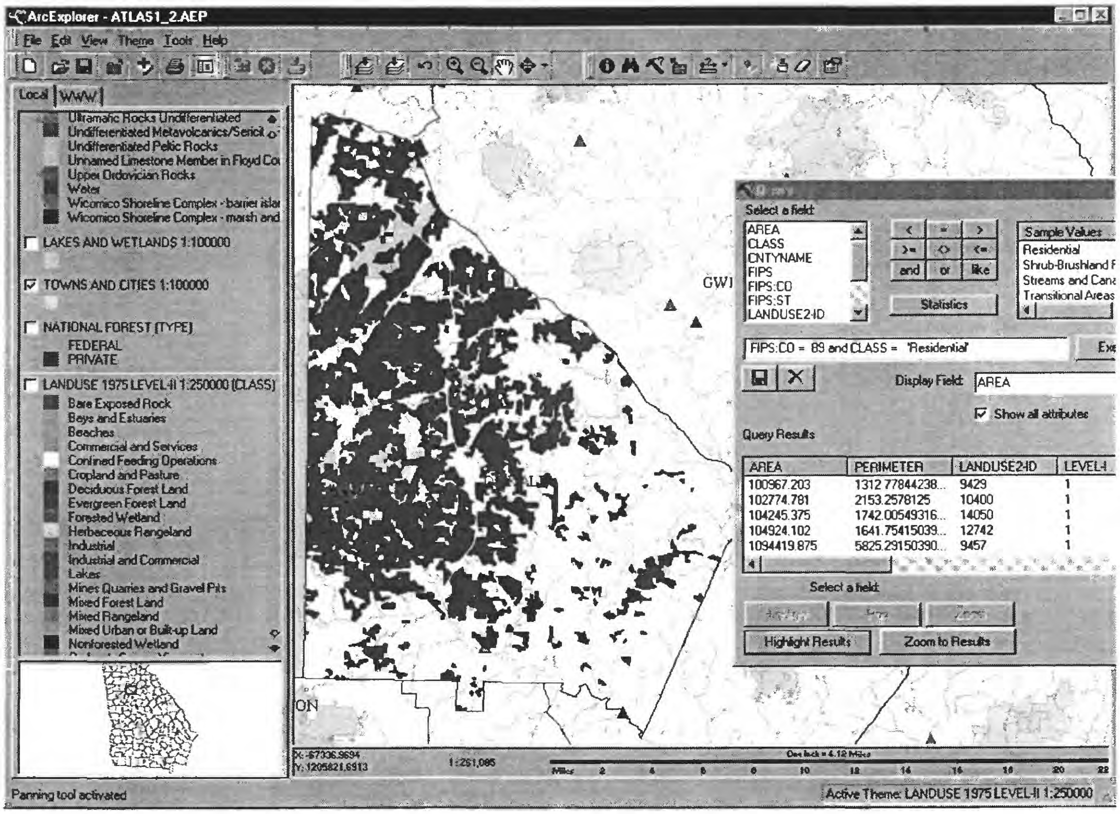

Figure 2. Selection and display of residential landuse by selected county (DeKalb).

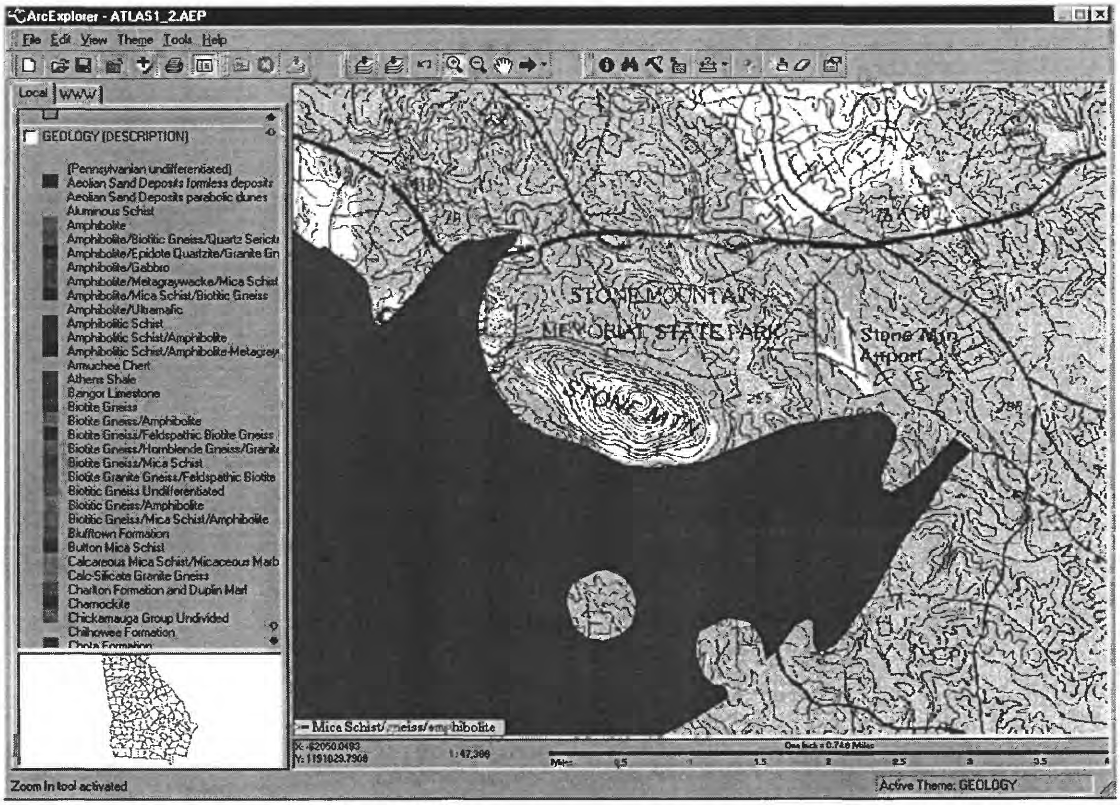

Figure 3. Mica schist/gneiss/amphibolite geologic formation in the vicinity of Stone Mountain, Georgia.

Characterizing the Fractured Crystalline-Bedrock Aquifers of North Carolina—A Federal and State Cooperative Study

Melinda J. Chapman[1], Charles C. Daniel, III[1], J. Wright Horton, Jr.[2], and William C. Burton[2]
[1]U.S. Geological Survey, 3916 Sunset Ridge Road, Raleigh, NC 27607
[2]U.S. Geological Survey, 12201 Sunrise Valley Drive, MS 926A, Reston, VA 20192

To address concerns regarding the potential for contamination of ground water in fractured crystalline-bedrock aquifers of the Piedmont and Blue Ridge provinces of North Carolina, the U.S. Geological Survey (USGS) initiated in 2000 a multiyear study with the North Carolina Department of Environment and Natural Resources, Division of Water Quality. Overall goals of the study include the characterization of ground-water flow systems at selected type-area study sites that are representative of broader hydrogeologic terranes and the identification of natural hydrologic and geologic controls that influence ground-water quality, availability, and transport. In most settings, conceptually the aquifer is a three-part system, consisting of fractured crystalline bedrock overlain by regolith, and a transition zone intermediate between unweathered bedrock and weathered regolith. The regolith-bedrock transition zone is a zone of relatively high transmissivity within the three-part system.

Type-area investigations are planned at six study sites within the Piedmont and Blue Ridge physiographic provinces in North Carolina. The study sites may range in size from a few acres to as large as a 16-square-mile watershed, depending on the research objectives. Soil and rock cores collected at each study area are being examined for features that may affect ground-water quality and movement. Borehole geophysical logs and cores are being used to describe the subsurface hydrogeologic setting, including lithology, foliation orientation, fracture occurrence and orientation, and flow characteristics. Surface resistivity surveys are being conducted to characterize the near-surface hydrogeology in areas between wells and surrounding areas that have no subsurface information. Two-dimensional surface resistivity methods are being used to determine depth to bedrock, characteristics of the overlying regolith and transition zone (collinear electrode arrangement), and to determine the presence or absence of directional bedrock anisotropy (square array electrode arrangement) related to steep fracturing.

Wells are being installed in clusters along transects in order to characterize flowpaths, hydraulic gradients, and water-level fluctuations. Aquifer tests and water-quality analyses at these study sites will contribute information on the hydrologic characteristics of the geologic units along the transects. Tracer tests and ground-water dating techniques will be used to estimate time-of-travel and to delineate flowpaths in the ground-water system. Analyses of major ions will be used to examine rock and water interactions and geochemical processes within each hydrogeologic terrane. Surface-water samples from study sites having lakes or streams will be analyzed to evaluate ground-water and surface-water interactions.

To date (July 2001), type-area investigations have begun at five of the six selected study sites, here described as the Langtree, Lake Wheeler, Reidsville, Bent Creek, and Cullasaja study sites. In the central Piedmont, 30 wells have been drilled at the 20-acre Langtree Peninsula study area on Lake Norman (Davidson College recreational facility campus) in Iredell County. Studies will address relations between ground water of the peninsula and surface water of Lake Norman. Weakly-foliated quartz diorite is the primary rock type, and is typical of the Charlotte Belt. Fractures generally are sparse and the regolith-bedrock transition zone thickness is variable. Six coreholes were drilled to collect samples of the regolith and bedrock, and to determine depth and thickness of the transition zone. Well installations at the Langtree study area include: 6 well clusters consisting of 3 wells each that tap the regolith, transition zone, and bedrock for determining vertical gradients and water-quality variation between permeable zones; and 12 shallow regolith wells for measuring variation in shallow ground-water flow directions. These wells were installed at selected locations along two down-slope transects. Also, a suite of borehole geophysical logs has been collected from each bedrock well for the purpose of lithologic and fracture characterization, including caliper, resistivity, natural gamma, fluid, acoustic and optical televiewer, and flowmeter logs. Real-time continuous ground-water-level data from well cluster MW-2 are available online at http://water.usgs.gov/nc/. Core drilling either has been completed or is ongoing at two other research sites.

At the Lake Wheeler study area in the eastern Piedmont (North Carolina State University (NCSU) research farm) in Wake County, geologic coring and well installation is complete. The primary rock type is the Raleigh gneiss, a fairly homogeneous quartzo-feldspathic gneiss on the west flank of the Raleigh metamorphic belt. Three clusters of observation wells were drilled containing three or four wells each that tap the regolith, transition zone (1-2 wells), and bedrock. In addition, a fourth bedrock well was installed for testing the hydraulic properties of the bedrock aquifer. Two additional shallow regolith piezometers were drilled near the proposed bedrock pumping well. Borehole geophysical logs also have been collected at the Lake Wheeler study area for subsurface lithologic and fracture characterization. The accessibility of the Lake Wheeler study area, near the North Carolina District office, makes it well suited for training and testing of equipment. Two-dimensional surface resistivity surveys were conducted at the Lake Wheeler study area and at a third research study area near Reidsville, discussed below.

The Reidsville study area in the western Piedmont encompasses the upper Wolf Creek watershed (about 16 square miles), in Rockingham County. Geologic mapping of this area in progress as part of the USGS Geologic Division Bedrock Regional Aquifer Systematics Study (BRASS) project. The Reidsville map area contains the NCSU Upper Piedmont Research Station where core drilling has been conducted. Well-foliated metasedimentary and metavolcanic rocks and felsic-to-mafic metamorphosed intrusive rocks in this area have varied compositions, as well as gentle to moderate dips complicated by folding, and are typical of the Milton belt in the western Piedmont. The rocks are highly fractured, having abundant low-angle fractures parallel to foliation, intersected by steeply dipping fractures. The regolith-bedrock transition is characterized by interlayering of rock types that weather differently. Data will be collected from well transects along a dip slope and cut slope to evaluate the potential controls of fractures parallel to foliation on ground-water flow paths and ages.

Coring is ongoing at the fourth research site in the Bent Creek Demonstration Forest (U.S. Forest Service) in Buncombe County (Blue Ridge Province). Detailed geologic mapping of the watershed was conducted by the North Carolina Geological Survey. The major group of rocks in that area are designated as part of the Ashe formation. Well installations similar to the Langtree and Lake Wheeler study sites are planned for Reidsville and Bent Creek.

Two additional type-area study sites are planned for the North Carolina Piedmont and Blue Ridge Ground-Water Study. Detailed geologic mapping is being conducted under the USGS Geologic Discipline BRASS project at a fifth research study area in the Cullasaja watershed in Macon County (Blue Ridge Province). The rapidly developing Cullasaja study area will be compared with the more pristine hydrologic environment of the Bent Creek watershed study area; both watersheds have similar bedrock geologic settings, being designated as part of the Ashe formation. A sixth study area also has been selected at an NCSU research farm near Asheville in Henderson County (Blue Ridge Province).

Arsenic Is Ubiquitous but not Elevated in Abandoned Coal-Mine Discharges in Pennsylvania

C.A. Cravotta, III[1], K.J. Breen[1], and R. Seal[2]
[1] U.S. Geological Survey, 215 Limekiln Road, New Cumberland, PA 17070
[2] U.S. Geological Survey, 12201 Sunrise Valley Drive, MS 954, Reston, VA 20192

Despite elevated concentrations in coal beds, dissolved As rarely is elevated in abandoned coal-mine discharges in Pennsylvania. For 140 samples collected in 1999, concentrations of As ranged from <0.03 to 15 µg/L in 41 anthracite mine discharges and from 0.10 to 64 µg/L in 99 bituminous coal-mine discharges (table 1). The pH of these discharges ranged from 2.7 to 7.3, with dominant modes at pH 3-4 and 6-7; concentrations of Fe ranged from 46 to 512,000 µg/L. The As was positively correlated with pH, alkalinity, Fe, SO_4, Cl, Br, and I and was inversely correlated with redox potential. Aqueous speciation computations indicated arsenate species ($H_2AsO_4^-$ and $HAsO_4^{2-}$) predominated.

Concentrations of As in Fe-rich precipitate (ochre) samples from 20 of the anthracite discharge sites ranged from <0.07 to 270 mg/kg. Generally, the concentration of As in the solids was positively correlated with the concentration of As and pH of the source water; the ratio of As concentrations in solution to As in solids (Kd) did not vary with pH. This trend could indicate increased capacity for attenuation of As by Fe compounds at higher pH. Poorly crystalline Fe(III) oxyhydroxides, such as ferrihydrite, tend to form under near-neutral conditions whereas Fe(III) oxyhydroxysulfates, such as schwertmannite, and crystalline Fe(III) oxyhydroxides, such as goethite, are predominant Fe(III) phases formed at low pH. Ferrihydrite could have greater sorption capacity for arsenate than goethite or schwertmannite. Nevertheless, the As that is associated with metastable Fe(III) compounds, such as ferrihydrite and schwertmannite, can be remobilized (1) upon conversion of metastable compounds to more stable phases such as goethite or (2) from reductive dissolution or acidic digestion.

Table 1: Composition of discharges from abandoned coal mines in Pennsylvania, 1999

[median(minimum-maximum)]

Coalfield & number of samples	pH	Redox Potential (mV)	Oxygen	Sulfate	Iron	Manganese	Arsenic
			(mg/L)				(µg/L)
Anthracite N=41	5.1 (3.0-6.3)	390 (170-770)	1.9 (0.3-11.1)	260 (36-1300)	15 (0.046-312)	2.9 (0.019-19)	0.62 (<0.03-15)
Bituminous N=99	5.2 (2.7-7.3)	340 (140-800)	.6 (0.2-11.5)	580 (120-2000)	43 (0.16-512)	2.3 (0.12-74)	2.0 (0.1-64)

Ground-Water Exploration and Development in Igneous and Metamorphic Rocks: Part I—Influencing Factors and Considerations

Thomas J. Crawford, P.G., Professor of Geology, Emeritus[1]
Randy L. Kath, P.G., Associate Professor of Geology[1,2]
[1] The State University of West Georgia, Carrollton, Georgia 30118
[2] U.S. Geological Survey, Georgia District, 3039 Amwiler Road, Suite 130, Atlanta, Georgia 30360

Exploration for and development of ground water in deformed igneous and metamorphic rocks in regions having a sub-tropical weathering environment are poorly understood because few studies have been conducted. Much of the funded research and many of the recent and current studies in this regard seem to focus on the physics of ground-water movement in fractured rock. During the last several decades these studies were driven by environmental containment and remediation problems and concerns. The objectives and goals of these environmental assessments differ from those required for exploration and development of water as a resource. For these programs, assessment of quantity, quality, and sustainability of the resource are of utmost importance.

Thirty-five years experience in the exploration and development of ground-water resources in igneous and metamorphic rocks of the southeastern United States has convinced the authors that, among the many factors that influence ground water in these rocks, the single most important factor is rock type. Rock type directly influences all other characteristics, including: reaction to physical and chemical stresses, type of weathering, depth of weathering, and topography. Without knowing the detailed geology of an area/site, all other factors influencing ground water lack a full and meaningful context.

To successfully explore and develop ground water in igneous and metamorphic rocks, an understanding of physical characteristics controlling ground-water movement is necessary. The interrelations, both inherent and spatial, of rock type, structure, type and depth of weathering, and topography must be known and understood. Each of these variables has numerous significant variations. Because these variations and the influence of each of these variables on ground water is relative rather than absolute, it becomes obvious that ground-water exploration and development in metamorphic and igneous rocks must be conducted on a site-specific scale.

The exploration and development approach proposed here begins with detailed site-specific geologic mapping at a scale of 1:24,000 or smaller to identify rock types. The mapping should be detailed enough to form an understanding of the major lithologic units and the structural features in the area. It is important to note any observable discontinuities in the rock—such as compositional differences (layering) and fractures (joints and/or faults). Topography and type of weathering must also be noted and taken into consideration in relation to the nature and extent of the recharge area. Lastly, the spatial relations of rock types and discontinuities to topography, type and depth of weathering, and recharge area are considered.

Though rarely of sufficient detail for siting water-well drilling locations, 1:24,000-scale geologic maps serve as an excellent beginning for more detailed study and analysis. Without such maps, geologists unfamiliar with the area of interest must spend a tremendous amount of time just getting familiar with mappable lithologic units. For this and many other reasons, it is important that efforts to conduct 1:24,000-scale geologic mapping by experienced qualified geologists in organizations such as the U.S. Geological Survey, state geological surveys, and universities continue.

Cytology of the Pallid Sturgeon Sperm Cell

Martin N. DiLauro[1], Wayne S. Kaboord[2], and Herbert Bollig[3]
[1]U.S.G.S.-Leetown Science Center, Northern Appalachian Research Laboratory, Wellsboro, PA
[2]Eaton Corporation, Research and Development, Milwaukee, WI
[3]U.S. Fish & Wildlife Service, Gavins Point National Fish Hatchery, Yankton, SD

The pallid sturgeon (*Scaphirhynchus albus*) is now restricted to large rivers of the central United States, primarily the Missouri and Mississippi River Drainages (Lee et al. 1980; Keenlyne et al. 1994). Until recognized as a separate species, it was mistakenly identified as the shovelnose sturgeon (*S. platorhynchus*) (Carlson et al. 1985; Etnier and Starnes 1993). This confusion left us very little regarding its early history and distribution (Etnier and Starnes 1993), and we contend that it is likely that the pallid sturgeon was once sympatric with the shovelnose sturgeon throughout much of its traditional range, which once included west slope Appalachian rivers. Many anthropomorphic effects have contributed to the very limited ranges of both these sturgeons. These include impoundments, pollution, channelization, and other habitat degradation.

The pallid sturgeon is listed as an endangered species in the U.S. by the Fish and Wildlife Service (UFWS)(Kallemeyn 1983). Both general (Booker et al. 1993; Pavlov 1993) and specific strategies or recovery plans (U.S. Fish & Wildlife Service 1992) call for the development of cryopreservation (cp) sperm banks to aid in the preservation of genetic biodiversity, ultimately leading to artificial propagation for recovery stockings in areas of extirpation (Booker et al. 1993). Sperm cell cytology descriptions will provide researchers with guidance regarding choice of cp method development (Stoss 1983; Leung and Jamieson 1991) and will provide a normal reference cell for comparison following the exposure of the rare sperm cells to the harsh liquid nitrogen cp temperatures (Lahnsteiner et al 1992; Lin et al. 1996). In addition, the structure of biological organisms are always an adaptation to function (DeRobertis and DeRobertis 1980), and such biological structures may provide important clues to aid in uncovering important life history mysteries (DeJong-Moreau et al. 2000).

Pallid sturgeon sperm cells were taken from five mature males at the UFWS Gavins Point National Fish Hatchery, Yankton, South Dakota. Briefly, cells were fixed in in fresh 2.5% paraformaldehyde plus1.5% glutaraldehyde in 0.2M sodium cacodylate buffer at pH 7.4. Sperm cell cytology and morphology were examined using JEOL 1200 EXII EXII transmission, and JSM 5400 scanning electron microscopes, respectively. This was performed at the Pennsylvania State University Electron Microscopy Facility (University Park, PA). Line drawings from other sturgeon species were performed to scale using digital caliper measurements from photomicrographs within respective cited references (DiLauro et al. 2001).

The sperm cell of this endangered species was similar to those of nearly all other described sturgeon sperm cells (Cherr and Clark 1984; DiLauro et al. 1999;2000;2001), which all share a gradual decreasing taper of the nuclear diameter from posterior to anterior, with the exception of the Atlantic sturgeon (DiLauro et al. 1998). Mean length of the radially symetrical palid sturgeon sperm cell body (acrosome + nucleus, i.e. head + midpiece) was approximately 6 μm, and the length of the flagellum was about 37 μm, resulting in a total cell length of about 43 μm. The pallid sturgeon sperm cell is intermediate in size between those of the Chinese and Atlantic sturgeons (Xu and Xiong 1988; DiLauro et al. 2001), however, resembles that of the lake sturgeon (DiLauro et al 2000) more closely in shape, but is shorter in overall length than that of the latter. The pallid sturgeon sperm cell differs from those of other sturgeons chiefly in the acrosomal area, with the posterolateral projections (PLP) being shaped like acute triangles. The PLP are also situated in a spiral arrangement about the longitudinal axis of the cell, and are much longer than those of other sturgeons studied. The acrosomal shape in cross-section also appears more like a hollowed-out cone than that of an acorn cap from an oak tree, as in other sturgeon previously studied. In addition, we were able to confirm the structural arrangement in the distal centriole as being composed of nine sets of microtubular triplets arranged about the periphery of the centriole, identical to the arrangement in the proximal centriole. We were not able to confirm this distal centriole arrangement in earlier studies with other species (DiLauro et al. 1998; 1999; 2000).

This information will be of use to researchers involved with cp method development. It will also be of potential use to fishery biologists, forensic biologists, zoologists, geneticists, reproductive physiologists, taxonomists, evolutionary biologists, and aquaculturists.

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Cytology of the Lake Sturgeon Sperm Cell

Martin N. DiLauro[1], Wayne S. Kaboord[2], and Kofi Fynn-Aikins[3]
[1]USGS-Leetown Science Center, Northern Appalachian Research Lab, Wellsboro, PA
[2] Eaton Corporation, Research and Development, Milwaukee, WI
[3] U.S. Fish and Wildlife Service, Lower Great Lakes Fishery Resources Office, Amherst, NY

The lake sturgeon (*Acipenser fulvescens*) historically inhabited freshwater rivers, lakes and large streams from Canada southward to northern Alabama, bounded on the east by the Appalachian mountains, with the western U.S. range less accurately defined. Although some stable populations of lake sturgeon exist in Wisconsin and in some areas of Canada, it is either extirpated or depleted in most of its traditional range. The lake sturgeon is known to have thrived in most west-slope Appalachian rivers. A few mature lake sturgeon have been found in western Appalachian reservoirs in the last 30-40 years as obvious vestiges of older populations, as no evidence of recent recruitment exists for those waters (Trautman 1981; Etnier and Starnes 1993). The lake sturgeon is listed as vulnerable to extinction (IUCN 1988; Campbell 1993) and as threatened by the American Fisheries Society (Williams et al. 1989). Despite protected status, migratory spawning routes to critical habitat continue to be blocked by impoundments, and critical habitat is disrupted or destroyed by other human intervention, leading to further losses in presently indigenous areas (LaHaye et al. 1992; Auer 1996).

Restoration plans in areas of extinction include sperm cryopreservation (cp) method development, which is recommended to preserve genetic biodiversity and allow for readily-available sperm in storage until fecund females are captured (Booker et al. 1993). Sperm cell morphology description will provide researchers guidance regarding methods of choice (Stoss 1983; Leung and Jamieson 1991) and provides normal cell description for comparison following exposure of cells to the harsh environment of cp (Lahnsteiner et al. 1992; Lin et al. 1996). In addition, structure of biological organisms are always an adaptation to function (DeRobertis and DeRobertis 1980), therefore biological structure will provide keys to unraveling life history information (DeJong-Moreau et al. 2000). Objectives were to describe the cytology of the lake sturgeon sperm cell.

Lake sturgeon sperm cells were collected from five mature males captured in the Des Prairies River near Laval, Quebec Canada. Briefly, cells were fixed in in fresh 2.5% paraformaldehyde plus 1.5% glutaraldehyde in 0.2M sodium cacodylate buffer at pH 7.4. Sperm cell cytology and morphology were examined using JEOL 1200 EXII transmission, and JSM 5400 scanning electron microscopes, respectively. This was performed at the Pennsylvania State University Electron Microscopy Facility (University Park, PA).. Line drawings from other sturgeon species were performed using digital caliper measurements from photomicrographs (DiLauro et al. 2000).

The cells of this depleted species had a distinct acrosome, a defined nucleus (head) region, a midpiece and a single flagellum. Sperm cells of this species exhibit radial symmetry, an elongate shape, and the presence of three endonuclear canals, similar to those of other sturgeons (DiLauro et al. 1999). The length of the lake sturgeon cell body (acrosome + nucleus + midpiece) is about 7 μm, and the length of the flagellum is 50 μm, resulting in a total cell length of 57 μm. Although slightly smaller in total length and width than the shortnose sturgeon sperm cell, that of the lake sturgeon is similar in cytology, overall size and shape. It shares a similarity in shape with all others compared with the exception of the Atlantic sturgeon sperm cell, which tapers decreasingly from head to tail in nuclear (head) width. The lake sturgeon sperm cell also has longer posterolateral projections than those of the Atlantic and shortnose sturgeon sperm cells (DiLauro et al. 1998; 1999). Our results suggest a more recent evolutionary linkage between the lake and shortnose sturgeons than with the Atlantic sturgeon. This work represents the first ultrastructural description of the lake sturgeon sperm cell and should have applications in cp restoration efforts involving this species. This information should be of potential use in the areas of fishery biology, forensics, zoology, reproductive physiology, taxonomy, evolutionary biology, and aquaculture.

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Geochemical, Mineralogical, and Environmental Characteristics of Metamorphosed Black Shales of the Central Appalachians, with Comparisons to Metalliferous Shales of the Northern Appalachians

Nora Foley[1], Scott Southworth[2], Arthur P. Schultz[1], Robert A. Ayuso[1], Gilpin R. Robinson[1], and Robert R. Seal[1]

[1] Mailstop 954 National Center U.S. Geological Survey, Reston, Virginia 20192

[2] Mailstop 926A National Center U.S. Geological Survey, Reston, Virginia 20192

ABSTRACT

Primary geochemical features of metamorphosed black shales that occur throughout the Central and Northern Appalachian regions reflect their original depositional environments, despite mineralogical reactions as a result of regional metamorphism and weathering. Near-surface reactions of sulfide minerals and water in these black shales causes acid drainage and the release of potentially toxic trace elements such as arsenic, copper, manganese, and mercury. High and anomalous contents of these elements represent pervasive and challenging problems associated with many rivers and streams in the Eastern United States. Acid rock drainage occurs naturally and is not associated with human activities. Simple weathering of rocks that host low-grade occurrences of iron sulfide minerals, for example, sedimentary pyrite layers in black shales is enough to pose potentially significant acid drainage problems. Release of potentially toxic trace elements such as arsenic, copper, manganese, and mercury that are either present as minute sulfide or sulfosalt mineral inclusions or structurally bound as trace elements in the lattice of the host sulfide minerals can also result in significant environmental impacts on surface and ground waters.

We have studied various shales (or their metamorphic equivalents) in the Central Appalachians to evaluate the potential for acid drainage and the release of toxic metals. Sulfidic and graphitic schists of Cambrian age that include the Anakeesta Formation (fig. 1) constitute part of the bedrock of the Great Smoky Mountains National Park (GSMNP). Metamorphosed sedimentary rocks of the Ocoee Supergroup that range in age from 545 million to 1 billion year old dominate the bedrock geology of the GSMNP (Schultz, 1998; Southworth, 1995; King and theirs, 1964). Rocks of the Snow Bird Group, Cades Sandstone, Rich Butte Sandstone, and rocks of the Great Smoky Group, which include Elkmont Sandstone, Thunderhead Sandstone, Anakeesta Formation, Copper Hill Formation, and Wehutty Formation, also underlie most of the park (Southworth, 1995). Carbonate rocks of the Ordovician Jonesboro Formation are exposed in the western end of the park near the Cades Cove area. This package of rocks comprises a number of blocks that are bound by faults that dip shallowly to the southeast (Southworth, 1995). These rocks have been metamorphosed to varying degrees by successive tectonic events throughout the Paleozoic.

The Anakeesta, Copper Hill, and Wehutty Formations are metamorphosed shaly rocks that contain trace to locally minor amounts of pyrite and pyrrhotite and graphitic organic matter, which imparts a black color to carbonaceous parts of the rocks. The ancient environment on the ocean floor where these sediments were deposited was anoxic (oxygen-poor) which promoted the accumulation of organic matter and the formation of pyrite in the sediments. Within the boundary of the Great Smoky Mountains National Park, copper-rich massive sulfide deposits hosted by shaly portions of the Copper Hill Formation occur at the Fontana and Hazel Creek mines (Robinson and others, 1992). Ground and surface waters draining the mines have elevated acidity and heavy-metal contents relative to waters draining sandstone or carbonate rocks in the GSMNP (Seal and others, 1998, 2000). Studies of secondary sulfate minerals associated with acid mine drainage in the Park has demonstrated that salt dissolution contributes to metal loadings and acidity in the surface waters and causes short-term perturbations in water quality

(Hammarstom and others, 2000). The U. S. Geological Survey (USGS), in cooperation with the National Park Service (NPS), has initiated a study of factors that affect water quality associated with the abandoned Fontana and Hazel Creek mines in Great Smoky Mountains National Park. An important aspect of evaluating the local impact of acid mine drainage is establishing the contributions from natural weathering of bedrock. The current climatic environment of the park is that of a humid temperate subtropical rainforest and the rocks are subjected to warm-to-sub-freezing temperatures. At the present time, thin layers of regolith develop on the shaly units in the park and during periods of high rainfall these have historically resulted in debris flows on the steep slopes underlain by the units (Schultz, 1998). The surface area exposure of fresh rock during debris flows serves to enhance naturally the rate of generation of acid from these rocks. Thus, weathering of iron sulfide minerals from shales and their metamorphosed equivalents by modern ground and surface waters is potentially a significant source of acid pollution in small creeks and streams throughout the Great Smoky Mountains National Park.

Diagnostic geochemical signatures (e.g., rare earth element, Ga, high-field strength elements) of shales in the Central Appalachians (e.g., Anakeesta Formation) are preserved even though the rocks have undergone regional metamorphism and weathering. Key geochemical features distinguish critical meta-shale units or sub-units within more variable geologic formations and can be used to establish mass gains and losses for the bulk shale compositions. This information is necessary to assess the rate and amounts of natural decomposition and contributions to the near-surface environment. For example, rare earth element distributions and patterns of the meta-shales fall into two distinct subgroups when compared to average North American shale compositions (NASC). Aluminum, Ga, and the high-field strength elements also appear to be immobile under these conditions of alteration. In contrast, many of the alkali elements and metals were highly mobile during regional metamorphism and subsequent weathering of the shale. The occurrence and distribution of iron sulfide minerals and patterns of sulfidation and oxidation in weathering of the Anakeesta Formation attest to the presence and distribution of regional sources of acid and metals (Fe, Cu). Mineralogical reactions that resulted from metamorphic overprinting and subsequent weathering of metal-bearing sulfide minerals (e.g., pyrite, pyrrhotite, marcasite, chalcopyrite) have generated and continue to generate a variety of intermediate and final alteration minerals of varying stabilities (e.g., bird's-eye pyrite and marcasite, covellite, colloform hematite, goethite, ferrihydrite, and amorphous $Fe(OH)_3$, Cu-oxyhydroxides, Cu-sulfate minerals, and Mn-hydroxides). Identification and characterization of primary, intermediate and final products of the reactions yield data that are useful for establishing lithologic-to-hydrologic pathways for the release of environmentally sensitive elements (H^+, Cu, Mn, As, Se, Hg, etc.). Geochemical and mineralogical modeling studies are now being employed to understand weathering rates and how their associated geochemical processes affect acid generation and metal release from sulfide-bearing portions of the Anakeesta Formation.

Mineralogical and geochemical comparisons (table 1) can be made between shales of the Central Appalachians (e.g., Anakeesta Formation) and black shales of the Northern Appalachians (e.g., Silurian Smalls Falls Formation: Guidotti and Van Baalen, 1999; Ordovician Penobscot Formation: Stewart, 1998; Robinson and others, 2000, Ayuso and others, 2001) and average North American and black shale compositions (e.g., Vine and Tourtelot, 1970). Sulfide-rich rocks of the Anakeesta Formation and some other meta-shales of the Central Appalachians contain trace to minor amounts of base-metal sulfide minerals, primarily pyrrhotite, with minor pyrite, and minor to trace chalcopyrite and Cu-sulfide minerals, and locally trace sphalerite and galena. In contrast, sulfide-bearing portions of the Penobscot Formation, a graphitic schist thought to have formed in a deep-sea, anoxic depositional environment (Stewart, 1998), contain trace to minor amounts of base-metal sulfide minerals primarily in the form of anisotropic pyrite, arsenian-pyrite, and pyrrhotite with accessory arsenopyrite, and trace to minor amounts of chalcopyrite, sphalerite, and galena, and other Pb, As, Ni, and Co-bearing sulfide minerals (Horesh, 2001; Foley and others, 2002). In the Northern Appalachians of Maine and New Hampshire, bedrock wells for domestic use have been shown to contain significant contaminants including high levels of arsenic (Ayotte and others, 1999). The differences in primary mineralogy for shales from the Central Appalachians compared to those from the north, have resulted in distinct geochemical and mineralogical characteristics for weathering products. Distinct characteristics that may, in part, control the chemistry of surface and ground waters that traverse the rocks. Understanding the mineralogical and geochemical factors that contribute to natural acid rock drainage in the Eastern United States can be useful in predicting expected background compositions and levels that may be used to accurately assess the environmental impacts of man-induced acid drainage.

Table 1. Representative compositional ranges for selected elements of shales from locations within the Eastern United States, excluding mines [1. This study; 2. Stewart, 1998; Robinson and others, 2000, Ayuso and others, 2001; 3. Guidotti and Van Baalen, 1999; 4. Wedepohl, 1969-1978]

Location	SiO2 (wt%)	Al2O3 (wt%)	Fe2O3 (wt%)	V (ppm)	As (ppm)	Cu (ppm)
Anakeesta Formation[1]	40.9-78.0	9.7-28.0	1.4-10.3	60-160	<0.6-77	<2-105
Penobscott Formation[2]	38.2-74.4	1.8-16.9	1.3-10.4	77-1600	0.2-94	13-70
Smalls Falls Formation[2,3]	58.4-74.6	12.6-19.7	3.9-19.5	81-166	2.8-15.0	
Average shale[4]	63.82	16.92	7.11	10-200 (5000+)	<0.2-50 (100+)	5-110 (300+)

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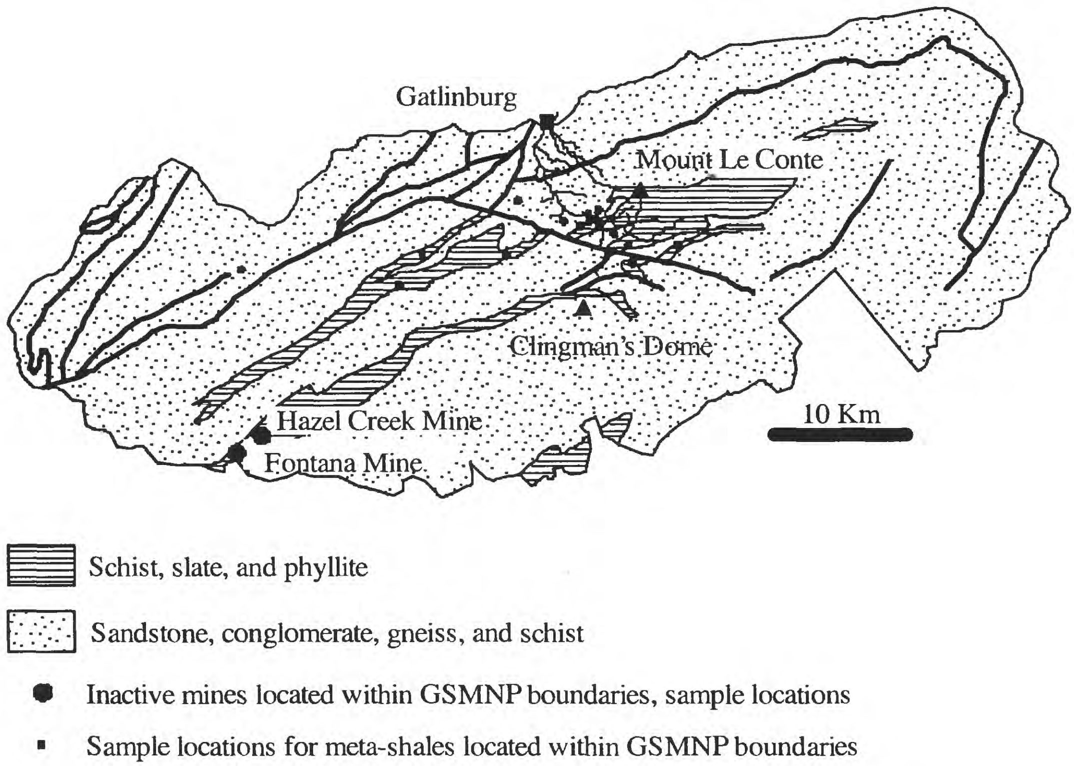

Figure 1. Generalized lithologic map of the Great Smoky Mountains National Park showing the distribution of various rock types and meta-shale sample locations. The location of the West Prong River in shown for reference. Heavy lines are fault boundaries. Modified from Southworth (1995).

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Indicator-Bacteria Concentrations in a River with Designated Uses of Drinking Water and Recreation, Metropolitan Atlanta, Georgia, 1999–2000—an Example from a Headwater Piedmont Watershed

Elizabeth A. Frick and M. Brian Gregory

DESCRIPTION OF PROPOSED PAPER

Metropolitan Atlanta is centered near the headwaters of the Chattahoochee River—which has a narrow, small watershed within the Blue Ridge and Piedmont physiographic provinces in northern Georgia. The Chattahoochee River is one of Georgia's most utilized water resources. The Chattahoochee River and Lake Sidney Lanier supply 72 percent of Metropolitan Atlanta's water supply and receive most of the region's treated wastewater as well as untreated urban runoff (Stevens, 2001). The population of the 10-county Metropolitan Atlanta area was more than 3.3 million people in 2000 (Atlanta Regional Commission, written communication, 2001). At the City of Atlanta's drinking-water intake, the Chattahoochee River watershed is 1,460 square miles, which is one of the smallest watersheds providing most of the water resource needs of any major metropolitan area in the US (Stevens, 2001). Microbial contamination is an issue in the Chattahoochee River watershed due to the high numbers of people using the Chattahoochee River as a drinking-water supply and recreational resource and the potential sources of contamination such as nonpoint runoff and treated and untreated wastewater effluent. Similar microbial contamination problems probably exist in other watersheds throughout the Appalachian region that have large population bases relative to the size of the watersheds and have designated uses of drinking water and recreation.

In 1999, the U.S. Geological Survey (USGS) in cooperation with the National Park Service, began a two-year study designed to evaluate microbial contamination in streams in and near the Chattahoochee River National Recreation Area (CRNRA). The CRNRA is comprised of 14 park units and the 48-mile reach of the Chattahoochee River downstream from Buford Dam which forms Lake Sidney Lanier to Peachtree Creek which drains most of downtown Atlanta.

The broad objectives of this study were to investigate the existence, severity, and extent of microbial contamination in the Chattahoochee River and eight major tributaries within the CRNRA. This was accomplished by (1) summarizing existing recent fecal-coliform data (Gregory and Frick, 2000) (2) conducting routine monitoring of three indicator-bacteria at three sites on the Chattahoochee River from March 1999 to April 2000 (3) conducting synoptic surveys at four mainstem and eight tributary sites during low-flow and storm-flow conditions and (4) conducting diurnal sampling at one mainstem site (Gregory and Frick, 2001). This proposed paper will summarize fecal-coliform bacteria, *E. coli*, and enterococci concentrations and potential variables affecting indicator-bacteria concentrations for the Chattahoochee River and its tributary streams from March 1999 to April 2000.

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A Low-Cost and Effective Method to Help Characterize Flow in Piedmont Fractured Crystalline Rock, Marietta, Georgia

Gerard J. Gonthier
U.S. Geological Survey, 3039 Amwiler Road, Suite 130, Atlanta, Georgia, 30360

ABSTRACT

Ground-water flow through Piedmont fractured crystalline rock is being characterized, in part, through the use of passive-diffusion-bag (PDB) samplers in creeks in Marietta, Georgia. PDB samplers are inexpensive to maintain and reliable to use (Vroblesky and Hyde, 1997). The target volatile organic compounds are chlorinated ethenes, particularly trichloroethene, emanating from nearby Air Force Plant 6 (AFP6). During low-flow conditions, streams are mostly fed by ground water. Fractured crystalline rock is a dominant rock type in Appalachia. The concentration of TCE and its degradation products and their locations within water from creeks during low-flow conditions are used to infer the source of the contamination and how it flowed through the crystalline rock to the end of the ground-water flow path into the ground-water-fed stream.

PDB samplers are suspended in surface water in continuous-flowing (ground-water-fed) streams near AFP6. Many volatile organic compounds including chlorinated ethenes readily diffuse across the polyethylene plastic lining of PDB samplers. Chemistry of water from the PDB samplers equilibrates to the average chemistry of the ambient water within 2 weeks.

Samples collected in 2000 October from PDB samplers indicated discrete locations where dissolved TCE was entering Rottenwood Creek, a ground-water-fed stream, near AFP6 (Gonthier and Waddell, 2001). PDB samplers are currently being installed in Rottenwood Creek as well as other ground-water-fed streams in the area. Other data-collecting activities to characterize flow in fractured crystalline rock on and near AFP6 include well logging, well-packer sampling, and aquifer tests.

Understanding how dissolved TCE flows through the subsurface helps both understand ground-water flow through fractured crystalline rock and human-health risks associated with dissolved TCE contamination in fractured crystalline rock. The use of PDB samplers in Appalachia will provide a low-cost, effective method to assess the presence volatile organic compounds flowing through fractured crystalline rock and into ground-water-fed streams.

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Water Quality of Springs in Carbonate Rock in the Upper Tennessee River Basin, 1997

Gregory C. Johnson
U.S. Geological Survey, 1820 Midpark Drive, Suite A, Knoxville, Tenn. 37921

In fall 1997 in the upper Tennessee River Basin, 35 springs in carbonate rock of the Valley and Ridge Physiographic Province were sampled for nutrients, bacteria, pesticides, and volatile organic compounds (VOC's) as part of the National Water-Quality Assessment Program (NAWQA). Of the 35 randomly selected springs 17 were utilized as untreated drinking-water supplies. Land use in the area surrounding the springs includes a mixture of urban, agricultural, and forested land use. Discharge from the springs ranged from 0.02 to 4.3 cubic feet per second, with a median value of 0.32 cubic foot per second.

Nitrate concentrations were low, generally less than 2 milligrams per liter (mg/L); however, fecal-indicator bacteria were detected in all 35 springs. Nitrate ranged from 0.091 to 2.17 mg/L, with a median concentration of 1.16 mg/L. Total coliform counts ranged from 10 to 1,900 colonies per 100 milliliters (col./100 mL) and *Escherichia coli* ranged from less than 1 to 660 col./100 mL. All water samples collected from the springs exceeded U.S. Environmental Protection Agency primary bacteriological drinking-water standards for public water supplies.

Pesticides and VOC's were detected frequently at low levels. Eight pesticides or degradation byproducts were detected in samples from 24 of the 35 springs. The most frequently detected pesticides were atrazine (57 percent of springs), deethylatrazine (atrazine-degradation byproduct, 54 percent), tebuthiuron (31 percent), prometon (17 percent), simazine (9 percent), and metolachlor (9 percent). Alachlor and p,p'-DDE each were detected once. Concentrations of the detected pesticides were less than the U.S. Environmental Protection Agency drinking-water maximum contaminant levels (MCL's), but some pesticides were detected more frequently in the springs than the national detection frequency of pesticides in ground-water samples from wells in other NAWQA studies. Of all the pesticides detected, the median concentration was 0.005 micrograms per Liter (μg/L), and the maximum concentration was 0.539 μg/L of tebuthiuron. Concentrations of VOC's detected in the springs were below applicable MCL's. As many as 9 VOC's were detected at a single spring; overall, 22 VOC's were detected in samples from 30 of the 35 springs. The majority of the VOC's detected were industrial-related compounds. The median VOC concentration was 0.03 μg/L, and the maximum concentration was 9.51 μg/L of methyl *tert*-butyl ether. The detection frequencies for VOC's in the springs were less than the national detection frequencies for wells in urban settings and greater than the national detection frequency for wells in rural settings.

Landscape Influences on Ambystomatid Salamander Populations in the Delaware Water Gap National Recreation Area

J.T. Julian, C.D. Snyder, J.A. Young, T.L. King, and D.P. Lemarié
USGS, Leetown Science Center, Aquatic Ecology Laboratory, 1700 Leetown Road, Kearneysville, WV 25430.

The Leetown Science Center's Aquatic Ecology Lab is conducting a three year, multidisciplinary study on the distribution, population status, and genetic structure of ambystomatid salamanders and in the Delaware Water Gap National Recreation Area (DEWA). Our goal is to describe landscape characteristics that are important to the distribution of ambystomatid salamanders so that park officials can make informed decisions pertaining to the management of artificial impoundments, beavers, roads and trails, riparian zones, and areas leased for agriculture. We will survey approximately 90 bodies of water each season that will represent landscape strata that have been shown to be important to the distribution of amphibians (vegetative cover, topography, hydroperiod, and habitat patch isolation). In addition, we will collect salamander embryos from a sub-sample of these ponds to look at the genetic structure of populations of ambystomatid salamanders throughout the park. The dynamic nature of vernal pool communities offers fertile ground for collaboration with other DOI scientists. Potential areas for collaboration include the use of remote sensing techniques to predict the location of vernal ponds, studying trophic relationships between invertebrate and larval amphibian communities, and compiling a range-wide study of the genetic structure of ambystomatid salamanders in the Appalachian region.

Amphibian Research and Monitoring in the Appalachian Region

Robin E. Jung, Karen C. Rice, C. Kenneth Dodd, Jr., W. Brian Hughes

The greatest biological diversity of amphibians north of Mexico occurs in the eastern United States, but amphibian populations in this area are subject to serious threats. Such threats include habitat degradation, fragmentation, and loss, as well as point and nonpoint source pollutants. In response to global concerns for amphibian health and survival, the USGS Amphibian Research and Monitoring Initiative (ARMI) was organized to monitor the status and trends of amphibians within the United States. Although ARMI is national in scope, two of its regions (Northeast and Southeast) encompass the Appalachian Region. Biologists and hydrologists are working together in the program to understand the biological and hydrological factors that affect amphibians and their habitats. The multidisciplinary effort links field research on amphibian life history and population status with water-quality and hydrological data collected at study sites. This poster describes ARMI research in progress in the Appalachian Region, primarily focusing on the Shenandoah and Great Smoky Mountains National Parks.

Ground-Water Exploration and Development in Igneous and Metamorphic Rocks: Part II—Case Histories from the Southeastern Piedmont/Blue Ridge Province

Randy L. Kath, P.G., Associate Professor of Geology [1,2]
Thomas J. Crawford, P.G., Professor of Geology, Emeritus[1]
Lester J. Williams[2]

[1] The State University of West Georgia, Carrollton, Georgia 30118
[2] U.S. Geological Survey, Georgia District, 3039 Amwiler Road, Suite 130, Atlanta, Georgia 30360

Growing demand for water, combined with the current drought in the Piedmont and Blue Ridge Provinces of northern Georgia, has pushed many local and municipal water systems to, or beyond, their limits. Many of these water systems rely almost completely on surface water. Ground-water resources in the Georgia Piedmont/Blue Ridge may prove to be a significant supplemental source of water to large surface-water systems. Despite the fact that Piedmont/Blue Ridge ground-water resources have been largely ignored, numerous communities have successfully operated ground-water systems for many years.

There is a general misconception that there is little ground water in igneous and metamorphic rocks in the Piedmont/Blue Ridge. Because of this, ground water typically has been ignored or deemed unreliable as a resource. Compounding this misconception, many techniques used for locating ground water in these kinds of rock are unreliable. Non-scientific and scientific methods for selecting drilling sites have further hindered developing ground water as a supplemental water source.

Unlike Coastal Plain aquifers, which can supply large sustainable quantities of ground water, igneous and metamorphic rock aquifers in the Piedmont/Blue Ridge are less predictable. These rocks have little primary porosity or permeability, and locating ground water as a resource requires that zones of secondary porosity and permeability, such as joints, stress-relief fractures, and other water-bearing openings in the subsurface be located as precisely as possible. To accomplish this, a good understanding of the site-specific geology is of utmost importance.

Geologic approaches for evaluating ground-water potential in igneous and metamorphic rocks have improved chances of locating sustainable sources of ground water. These evaluations begin with detailed site-specific geologic mapping to identify: 1) rock type(s); 2) discontinuities, due to compositional differences (layering) and fractures (joints and/or faults); 3) topography; 4) type and depth of weathering; 5) nature and extent of the recharge area; 6) spatial relationships of rock types and discontinuities to topography, type and depth of weathering, and recharge area.

Case studies from Spalding, Carroll, and Gwinnett Counties, Georgia, are presented to show examples where communities have conducted ground-water exploration programs only to drill dry holes or low-yielding wells, even where the exploration programs used "high-tech" approaches that were thought to be the best tools for finding ground water. The flaw in many of these exploration programs is the lack of knowledge of site-specific geology. Without basic geologic data and an understanding of the detailed characteristics of the rocks in the targeted area, exploration programs have had little success.

Applying sound geologic methods for evaluating ground-water potential in igneous and metamorphic rocks have improved chances of locating sustainable sources of ground water in the Piedmont/Blue Ridge. When an appropriate scientific approach is taken, the probability of locating successful water wells is greatly increased.

Monitoring Coliform Bacteria in a Piedmont River Arising from the Appalachian Region of Northern Georgia

Stephen J. Lawrence
U.S. Geological Survey, 3039 Amwiler Road, Suite 130, Atlanta, GA 30360

Because of historically high levels of indicator bacteria in the Chattahoochee River, the concept of a bacteria alert network was proposed as a means to inform people when bacteria levels in the river exceed U.S. Environmental Protection Agency (USEPA) criteria. Thus, a program of bacteria monitoring called BacteriALERT was initiated on the Chattahoochee River within the Chattahoochee River National Recreation Area (CRNRA, National Park Service) in Fall 2000. The CRNRA contains about three-fourths of all public green space in a 10-county area of Metropolitan Atlanta, Georgia. In 1999, the recreation area attracted about 2.9 million visitors with nearly 30 percent of those participating in water-based recreation. Within the area of the bacteria alert network, drinking water and recreation are the designated uses for the Chattahoochee River.

BacteriALERT is a partnership between State and Federal agencies and non-government organizations. This partnership includes the Georgia Environmental Protection Division, the National Park Service, and the U.S. Geological Survey (USGS) and non-governmental organizations such as the Upper Chattahoochee RiverKeeper, Georgia Conservancy, Trust for Public Lands.

The main objective of this network is to collect and analyze water samples for total coliform and *Escherichia coli* (*E. coli*) bacteria at two sites on the Chattahoochee River upstream from Atlanta, Georgia, and post the results on a publicly accessible web site within 24 hours of data collection. A second objective is the statistical analysis and interpretation of these data under a wide range of seasonal, weather, and river conditions.

Water samples are collected four days per week (Monday-Thursday) using USGS-approved methods. The method uses a weighted-yoke to hold a sterile, narrow-mouth, 1-liter polypropylene bottle. A single, vertically integrated sample is collected at the center of flow. Turbidity and specific conductance in collected samples are measured in the laboratory. All analyses are completed in the bacteria laboratory at the USGS office in Atlanta, Georgia.

The bacteria analysis for total coliform and *Escherichia coli* is an enzyme substrate method called Colilert that is analogous to the commonly used multiple tube method. Bacteria counts are expressed as a most probable number (MPN) per 100 milliliters (mL). Three or four different dilutions are prepared for each site by adding an aliquot of sample to sterile, deionized/distilled (DI) water to produce 100 mL of liquid. A powdered reagent is added to each dilution bottle and the mixture added to a sterile, plastic tray containing 97 wells and incubated for 20 hours at 35 degrees Celsius. The wells produce a yellow color when total coliform bacteria are present and fluoresce under UV light when *E. coli* are present. Quality control is maintained by using sterile technique, collecting duplicate samples, and analyzing split samples using membrane filtration methods. Total coliform, *E. coli,* and fecal coliform bacteria are intermittently analyzed using the standard membrane filtration methods. Total coliform and *E. coli* filters are incubated in HACH's m-Coliblue24 broth.

In the twelve months of operation, a broad spectrum of people have visited the BacteriALERT web site for bacteria information before using the river. Many of those using the site are students, teachers, fishermen, kayakers/river rafters, and university rowing teams.

Statistical analysis has shown that (1) fecal coliform levels are strongly correlated with the total coliform and *E. coli* levels using the Colilert method; (2) only 15 to 35 percent of samples exceeded the U.S. EPA criteria; (3) *E. coli* levels exceeded the criteria when turbidity measurements were greater than 25 to 45 NTU; (4) *E. coli* levels are strongly related to river turbidity which are strongly related to increases in river discharge during and after rain storms; and (5) E. coli levels are higher during summer months than during winter and spring months.

In comparison, limited sampling in a stream that drains a natural, non-urban, undeveloped watershed within a state park shows that *E. coli* levels commonly exceeded the USEPA criteria, especially during the summer months. The highest E. coli count to date in this stream is 3,500 colonies /100 mL, more than 10 times the USEPA criteria of 235.

Terrestrial Carbon Sequestration – A Potential Land-Use Management for Mitigation of Greenhouse Gas Emissions

H.W. Markewich and G.R. Buell
U.S. Geological Survey, 3039 Amwiler Rd., Suite 130, Atlanta, GA 30360-2824

If carbon sequestration is to be seriously considered as having a role in reduction of greenhouse gas (GHG) emissions, then it is imperative to know how terrestrial carbon is cycled and distributed on the landscape. Only then can we estimate the cost/benefit ratio of using terrestrial carbon sequestration to offset the effects of GHG emissions. In most terrains, the most stable long-term reservoir for terrestrial carbon sequestration is the soil. Analysis of soil organic carbon (SOC) storage data for the Appalachian region indicates distinct associations between spatial patterns in SOC distribution and regional variation in parent material (rock type), climate (elevation/aspect), and vegetation. Data analysis also suggests that SOC inventory estimates vary widely, depending on which datasets are used for storage calculations (aggregate versus site-specific), and on the scale of the map to which the data are linked. Understanding the factors controlling SOC storage and the reliability of the SOC inventory data is the first step in identifying those areas with the greatest potential to sequester SOC. These areas can then be given the highest priority for targeted efforts in land restoration/protection.

For the past several years the U.S. Geological Survey (USGS) has been investigating the role of SOC in the global carbon cycle. Data from these investigations now allow us to begin to (a) "map" SOC at national, regional, and local scales; (b) calculate present SOC storage at the land surface; (c) identify those areas with the greatest potential to sequester SOC; and (d) identify where these areas are coincident, and where they could be included, with lands targeted by local, State, and Federal agencies for watershed protection, "greenspace" development, or animal migration-route connection.

The initial task in achieving the first three objectives is to determine current levels of terrestrial SOC stocks and enable estimates to be made of net changes in SOC stocks related to landuse and climate change. The most readily available method to estimate SOC inventory for the surface meter of any land area in the United States is to use either of two U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) geographic databases (U.S. Department of Agriculture, 2001a,b)—the Soil Survey Geographic database (SSURGO, 1:24,000) or the State Soil Geographic (STATSGO, 1:250,000) database. These databases provide a powerful GIS framework for calculating SOC inventories at scales ranging from county (SSURGO) to national (STATSGO). Soil series comprising SSURGO map units are characterized by soil-attribute and related ancillary data in the USDA-NRCS Map Unit Interpretations Record (MUIR) database (U.S. Department of Agriculture, 2001c). STATSGO map units are characterized by a more generalized version of MUIR, the USDA-NRCS Soil Interpretations Record (SIR) database (only available as part of STATSGO). MUIR and SIR are aggregate databases that include variables such as organic matter, texture, slope, water content, and vegetative cover to describe map-unit components (soil series).

Although MUIR and SIR are similar, neither database captures the spatial variability in soil properties at the series level. Differences between SSURGO-scale and STATSGO-scale estimates of SOC inventory are primarily influenced by scale-related differences in map-unit composition. Soil-series characterization by MUIR/SIR data is not statistically consistent and therefore provides, at best, a semi-quantitative estimate of SOC inventory.

Compilation, synthesis, and linkage of site-specific soils data to SSURGO/STATSGO map units provides an empirical alternative to MUIR/SIR. Comparative estimates of SOC inventory for selected areas within the Appalachian Highlands physiographic division (Fenneman, 1938) were calculated using SSURGO map units linked to MUIR, STATSGO map units linked to SIR, and site-specific data linked to both sets of map units. The site-specific soils data included approximately 10,000 soil pedon records from the USDA-NRCS National Soil Survey Center Soil Survey Laboratory Characterization Database (U.S. Department of Agriculture, 2001d); state databases for Arkansas (E.M. Rutledge, University of Arkansas, Fayetteville, Arkansas, unpub. data, 2001), Illinois (University of Illinois, 2001), Louisiana (Schumacher and others, 1988); and numerous small databases provided by individual researchers. Differences in the results were related to map scale, the percentage of each map unit represented by data, and how well contributing soil series were represented by data.

Initial comparative estimates of SOC storage demonstrate that STATSGO map units are the most appropriate for regional analysis, whether they are linked to their associated SIR data or to site-specific data, and that SSURGO map units linked to site-specific data provide the information needed for county-level analyses directed at identifying specific areas with high potential for SOC sequestration. It is these areas that are, or will be, of greatest interest to those parties charged with the regulation of landuse directed at increasing carbon sequestration.

SOC storage data for seven western North Carolina counties in the Blue Ridge and Piedmont physiographic provinces (table 1) indicate elevation as a major control on carbon storage in the ridge/sideslope and footslope soils. High-elevation ridge/sideslope and high-elevation footslope soils generally have higher SOC storage than low-to-medium-elevation soils in these landscape positions. This elevation gradient is possibly related to elevational changes in temperature, moisture, and vegetation. Slope angle also appears to be a control for footslope soils, with SOC storage increasing as the slope increases. There are no data available for high-elevation floodplain/terrace soils. SOC storage values for low-to-medium elevation floodplain/terrace soils are higher than those values for either ridge/sideslope or footslope soils at similar elevations. Thus one can postulate that higher elevation ridges and sideslopes, higher elevation footslopes in steep terrain, and lower elevation alluvial valleys are possible environments with greater SOC sequestration potential. Analysis of geographic patterns in SOC storage within the context of climate, geomorphology, and vegetation can provide a process-based approach to the identification of these areas within the landscape.

Ongoing efforts promise to show that merged SOC inventory and land-use databases can be used to identify areas with high SOC sequestration potential that are coincident with lands targeted by local, State, and Federal agencies for watershed and well-head protection, floodplain and wetland restoration and(or) protection, cropland reserve programs, mammal and bird migration route connection, and urban/suburban greenspace-corridor creation/restoration/connection. Identifying and studying the characteristics of landscape positions with high SOC sequestration potential may also result in additional land corridors being considered for, or designated as, set-aside areas for carbon sequestration. Some examples include land buffers along interstate highways, rail lines, and utility rights-of-way.

The actions required to successfully implement these programs require the cooperation of individual, corporate, municipal, state, and federal land owners. To obtain this degree of cooperation, there are two essential requirements: (a) that identification of priority areas be based on as much detailed geologic, geomorphic, biologic, and socio-economic data as can be obtained; and (b) that data syntheses be made available so that each land owner can assess the potential gains or losses of the recommended land-use changes. Ongoing efforts of the USGS to address these needs include:

- compilation and synthesis of site-specific data needed to estimate carbon storage and inventory in the soils, reservoir sediment, wetlands, and lakes of the conterminous United States;
- characterization of present-day carbon storage by landscape feature and environment; and
- prediction of potential carbon storage for land areas identified as possible reserves for carbon sequestration.

Table 1. Soil organic carbon (SOC) storage in the top twenty centimeters for six western North Carolina counties, based on the USDA Natural Resources Conservation Service Soil Survey Geographic (SSURGO) database map units

[Comparative SOC storage estimates are presented by landform and elevation for Ashe, Jackson, McDowell, Mitchell, Polk, Rutherford, and Yancey Counties in the Blue Ridge and Piedmont physiographic provinces of North Carolina. Elevation ranges -- low, 0-2000 feet; medium, 2000-4000 feet; high, 4000+ feet. Slope ranges -- low, 0-15 percent; medium, 15-40 percent; high, 40+ percent. SOC storage estimates for SSURGO map units in these counties are based on two data sources: 1 - site-specific soil pedon data linked to the map units by soil series (SSURGO map-unit components) and 2 - SSURGO layer-table data linked by soil series.]

			SOC storage based on site-specific pedon data		SOC storage based on SSURGO layer tables	
Landscape position	**Elevation range**	**Slope range**	**Number of SSURGO map units[1/]**	**Median, minimum, and maximum storage (kg/m^2)**	**Number of SSURGO map units**	**Median, minimum, and maximum storage (kg/m^2)**
ridge/sideslope	low	low-medium	1[31]	**3.3** 3.3-3.3	32	**1.4** 0.9-2.2
	medium	medium	63[11]	**3.8** 2.9-10.8	74	**3.4** 2.0-16.3
		high	108[3]	**4.8** 1.9-17.5	111	**4.8** 1.3-15.6
	high	medium	15	**9.7** 9.2-10.4	15	**15.2** 6.7-67.4
		high	25[6]	**9.2** 8.6-9.8	31	**14.0** 8.4-17.2
footslope	low	low-medium	0	--	11	**1.1** 1.1-2.0
	medium	low	9	**3.6** 2.7-4.2	9	**2.4** 2.2-7.4
		medium	49[1]	**6.0** 1.6-10.5	50	**6.7** 0.4-16.6
		high	2	**6.8** 6.8-6.8	2	**10.9** 10.9-10.9
	high	medium	7	**11.6** 11.5-12.3	7	**11.9** 11.8-13.0
		high	3	**13.1** 13.1-13.1	3	**6.8** 6.8-8.3
floodplain/terrace	low-medium	low-medium	19[39]	**6.5** 1.9-11.5	58	**5.1** 1.1-55.6

[1/]Numbers in square brackets are the number of SSURGO map units for which there are no data available for any of the soil series in the map unit.

Some examples of active projects include:

New Jersey Department of Environmental Protection *Well Head Protection Plan*, Division of Science and Research, Geological Survey, <http://www.state.nj.us/dep/dsr/wellhead.pdf>

Tennessee Department of Environment and Conservation, Division of water Supply, *Wellhead Protection Program*, <http://www.state.tn.us/environment/dws/wellhdbro.html>

U.S. Environmental Protection Agency (EPA), *Upper Basin Project*, floodplain restoration and sustainability, St. Johns River Water Management District, <http://yosemite.epa.gov/water/restorat.nsf/>

EPA *Southeastern Ecological Framework Project*, GIS-based analysis to identify ecologically significant areas and connectivity, <http://www.geoplan.ufl.edu/epa/>

US Department of Agriculture, *Crop Reserve Enhancement Program (CREP)*, for example, in Missouri, 50,000 acres of highly erodible and environmentally sensitive cropland along streams that supply 83 reservoirs are being retired to CREP (USDA Office of Communications, News Release No. 0316.00) <http://www.fsa.usda.gov/pas/news/releases/2000/09/0316.htm>

Cook County, Illinois *Forest Preserve District*, <http://www.co.cook.il.us/secretary/HomePage_Links/whats_cookin_in_cook_county_book.htm#COOK COUNTY FOREST PRESERVE DISTRICT>

City of Chicago's *The Chicago Brownfields Initiative* *<http://www.ci.chi.il.us/Environment/Brownfields/Index.htm>*.

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Comparison of Bacterial Source-Tracking Methods and Investigation of the Sources of Fecal Contamination to Ground Water in Berkeley County, West Virginia

Melvin Mathes[1] and Don Stoeckel[2]
[1] U.S. Geological Survey, Charleston, West Virginia
[2] U.S. Geological Survey, Columbus, Ohio

Escherichia coli, indicators of fecal contamination, were detected in 16 of 50 domestic water wells that were sampled during the summer of 2000 in Berkeley County, West Virginia. This region is partially underlain by karstic limestone where ground water flows quickly and commonly interacts with surface water, which makes it difficult to link fecal contamination in ground water to aboveground sources. Bacterial source tracking will be a valuable tool to aid the State and County in their efforts to identify and control fecal contamination in ground water and will provide a tool for other bacterial contamination studies. Because the field of bacterial source tracking is in its infancy, no consensus is available regarding the best methods to address fecal contamination sources in environmental settings. This investigation will compare seven bacterial source-tracking methods for their ability to discriminate *Escherichia coli* isolates from feces of different source-animal categories in Berkeley County. Method performance will be assessed by challenging a library of known-source isolates with a blind library of isolates. The animal sources of the blind-library isolates will be known to the project chief but not to any of the analyzing laboratories. Method performance will be assessed by the average rate of correct classification for isolates from each source group, the rate of false-identification within each source group, materials cost, and time cost. The best method in the comparison will be used in a field study to associate ground-water-contaminating *Escherichia coli* with their sources.

Forest Change Within Shenandoah National Park

David D. Morton[1], John A. Young[1], and Dan Hurlbert[2]
[1] U.S. Geological Survey, Leetown Science Center, Kearneysville, WV
[2] National Park Service, Shenandoah National Park, Luray, VA

Due to fire, insect pests, weather events, human activity, and disease, the forests of Shenandoah National Park have undergone a variety of changes. This poster highlights geospatial technologies being used to analyze the past to better understand the present and future. Remote sensing is a powerful tool for revealing land cover change. A time series of Landsat Thematic Mapper imagery is being used to track the health of eastern hemlock (*Tsuga canadensis*) stands. These trees are being defoliated by the hemlock woolly adelgid (*Adelges tsugae*), an exotic aphid-like insect. By using a vegetation index, calculated from multispectral imagery (such as TM), it is possible to observe hemlock health over time and locate areas of change. With this information, it may be possible to predict which stands are most vulnerable to future infestations. Similar change detection techniques can be used to map one-time events such as the 1995 flood of the Staunton River. This 500+ year flood scoured several riparian areas causing significant change to stream drainages.

Historical data is instrumental in mapping current vegetation communities. Geographic representations of fire history, gypsy moth defoliation, hurricane and ice damage, along with analyses described above aid researchers in understanding forest flora and structure. Past maps of vegetation, including an exceptional digitized version of a 1941 report, reveal important information about forest age and species occurrence. All of this information about forest history will be combined with current remotely sensed data and ecological modeling (see poster by Young et al.) to get a detailed map of present vegetation community distribution.

Effect of Clearcutting on Nitrogen Export from a Watershed in the Catskill Mountains, New York

Peter S. Murdoch and Douglas A. Burns
U.S. Geological Survey, 425 Jordan Rd., Troy, NY 12180

The Catskill Mountains of New York receive high rates of nitrate deposition (10-12 kg/Ha/yr). and many streams have measurable nitrate concentrations throughout the growing season. Approximately 16 hectares of a 22-hectare watershed in the Catskills was clearcut during the winter of 1996-97. Soil- and surface-water quality was monitored for 4 years prior to the cut, and monitoring has continued since. Nitrate concentrations in stream samples peaked at 1,400 µmoles/liter during the first summer following cutting. Patterns of stream nitrate concentrations in the 4 years following the cut are strongly similar to concentrations observed in the 4-year postcut period at Watershed 5 in the Hubbard Brook Experimental Forest. Nitrate concentrations in the Catskill clearcut appear to be rising to pre-cut levels during year 5 of the postcut period, while the 5th-year concentrations at Watershed 5 were at or near detection. Nitrification rates in Catskill watersheds are high relative to those reported from other areas of the Northeast (5-7 g $N/m^2/yr$), and showed little change as a result of the cut. The comparison of the two logging studies in watersheds receiving differing rates of N deposition suggests both short-term similarities and long-term differences in rates of nitrogen export following clearcutting.

Paleozoic through Cenozoic Uplift, Erosion, Stream Capture, and Deposition History in the Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain Provinces of Tennessee, North Carolina, Virginia, Maryland, and District of Columbia

C.W. Naeser,[1] N.D. Naeser,[1] M.J. Kunk,[2] B.A. Morgan, III,[1] A.P. Schultz, [1]
C.S. Southworth,[1] and R.E. Weems[1]
[1] U.S. Geological Survey, 926A National Center, Reston, VA 20192
[2] U.S. Geological Survey, MS 963, Denver Federal Center, Denver, CO 80225

Fission-track (FT) analysis of zircon and apatite is helping define the Paleozoic through Cenozoic history of the Valley and Ridge (VR), Blue Ridge (BR), Piedmont (P), and Coastal Plain (CP) provinces of the Eastern United States. The oldest zircon FT ages from the VR and western BR are significantly older than those of the eastern BR and P provinces. This is apparent in the ranges of both sample ages and single-grain ages.

		FT age range (Ma)		
	Stratigraphic	Weighted mean sample ages		Single-grain ages
Province	age	Apatite	Zircon	Zircon
VR	Paleozoic	~200	~560	~380--~1160
western BR	Proterozoic-Paleozoic	~100--~155	~315--~920	~235--~1790
eastern BR	Proterozoic-Paleozoic	~95--~185	~265--~380	~200--~730
P	Proterozoic-Mesozoic	~130--~200	~260--~300	~200--~360
CP	Miocene	no apatite	~390	~45--~1340
CP	Cretaceous-Oligocene	~130--~155	~175--~280	~45--~795

Some VR and western BR rocks were never buried deeply enough during the Phanerozoic to obtain temperatures sufficiently high (>~225°C) to totally reset their zircon FT ages. In contrast, most zircon ages from the eastern BR and P show significant cooling from >225°C at ~300-280 Ma, most likely related to emplacement of major Alleghanian thrust sheets. Apatite FT data suggest that BR and P rocks underwent relatively slow, continuous cooling during the Mesozoic and Cenozoic, passing through the apatite FT closure temperature (~90-100°C) at a rate of about 16 m/m.y.

FT ages of detrital zircon in shallowly buried (<411 m) rocks in the CP reflect FT ages in the source terrain. The data suggest that the P and eastern BR were the major source of detritus from Cretaceous through Oligocene time. Old zircons comparable in age to those in the western BR and VR do not appear in CP rocks until early or middle Miocene. Preliminary interpretation is that major drainage from the western BR and VR was to the west prior to the Miocene--major east-flowing Mid-Atlantic rivers did not breach the Blue Ridge until early or middle Miocene time.

Concentration-Discharge Patterns in Acid-Neutralizing Capacity During Stormflow in Three Small, Forested Catchments in Shenandoah National Park, Virginia

Karen C. Rice[1], Jeffrey G. Chanat[2], George M. Hornberger[2], and James R. Webb[2]
[1]U.S. Geological Survey, P.O. Box B, Charlottesville, VA 22903
[2]Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22903

To provide insight into runoff processes, we examined variability of concentration-discharge (c-Q) plots of acid-neutralizing capacity (ANC) using a multiyear, multistorm hydrological and hydrochemical data set for three forested catchments in Shenandoah National Park, Virginia. The shape and rotational direction of c-Q plots (clockwise or anticlockwise) have been explained in the context of conservative mixing of three end members—surface-event, soil, and ground water. The streams draining the catchments represent a gradient in baseflow ANC, which is controlled by the underlying geology. We observed a trend in the fraction of anticlockwise rotation patterns, from the highest in the most acidic catchment to the lowest in the least acidic catchment. On the basis of previous modeling of c-Q plots, the trend across the catchments can be explained by differences in the concentration of the three end members, whereby the greater the differences (i.e., in the least acidic catchment), the fewer anticlockwise rotation patterns were observed. Differences in the relative volume and timing of the end members contributing to stormflow, ultimately controlled by the underlying geology, also may have contributed to the trend. Discriminant function analysis indicates that pre-storm baseflow ANC is an important predictor of rotation direction in two of the catchments; however, the predictive strength of the model decreases from the most acidic to the least acidic catchment. Variation of rotation patterns within a given catchment and across similar catchments can provide insight into factors and processes that influence runoff generation and solute transport.

GEODE – An Interactive Data Retrieval, Display, and Analysis Internet Application

A. Schultz, R. Wardwell, and M. Levine

GEODE (Geo-Data Explorer) "http://geode.usgs.gov" is an Internet-based, USGS data delivery system that provides digital information to the desktops of clients and users by means of an innovative geographic information system (GIS) technology. GEODE uses a custom GIS interface developed by the USGS that allows policy-makers, land and resource managers, educators, private industry, and others to search for maps and databases, create custom map and data downloads, control map appearances, and display multiple layers of data for analysis. GEODE consolidates data from a variety of sources in order to simplify the data mining and decision-making process. GEODE was originally designed to disseminate energy related information including coal, oil, and gas datasets. However GEODE has developed to include additional datasets from the entire USGS Geologic Discipline, and it now provides selected data on volcanoes, earthquakes, geologic maps, climate change, ecosystems, minerals, coastal, and marine issues. These data sets may be combined with additional data layers and imagery such as satellite images, digital elevation models, transportation systems, census tracts, and population data. GEODE is a fast, accessible, spatial research and analysis tool that allows the user to perform resource estimates and risk assessment without the need for special hardware, software, or training.

Landscape Influences on Aquatic Assemblages: Fish, Bugs, and Salamanders

C.D. Snyder, J.A. Young, D.P. Lemarie, R.F. Villella, D.R. Smith, and Z.B. Johnson

As with birds, mammals and other terrestrial assemblages, the distribution and abundance of aquatic species are fundamentally linked to the landscape. Scientists at the Leetown Science Center's Aquatic Ecology Laboratory (AEL) conduct research aimed at better understanding the linkages between terrestrial and aquatic components of Appalachian ecosystems. This poster describes examples of basic and applied research conducted at AEL that evaluate landscape influences on aquatic assemblages. Showcased studies include research designed to: 1) determine the effects of urban and agricultural land use on stream fish assemblages in Ridge and Valley watersheds (VA, WV), 2) predict the impact of forest pests on aquatic biodiversity in the Delaware Water Gap National Recreation Area (PA, NJ), 3) assess aquatic invertebrate recovery patterns to a major flood in Shenandoah National Park (VA), and 4) develop empirical models that relate amphibian breeding pond selection to landscape and pond habitat factors in the Canaan Valley National Wildlife Refuge (WV). The poster is meant to depict the scope of landscape studies conducted at the lab and focuses on objectives, major findings, and opportunities for cross-discipline collaboration. Taken together, results of these studies highlight the need to integrate landscape-level information in order to manage aquatic ecosystems in the Appalachian region.

Hydrologic Hazards and Streamgaging Needs in the Appalachian Mountain Region

Timothy C. Stamey, Hydrologist; and Keith McFadden, Computer Specialist, Georgia District, WRD

Hydrologic hazards from floods, droughts, and landslides are major issues of concern in the Appalachian Mountain region. Often, hydrologic hazards result in loss of human life, property damage, disruption of lives, and various economic losses. The major issues are minimizing the potential adverse effects from hydrologic hazards; protecting and enhancing water resources for human health, aquatic health, and environmental quality; and contributing to wise physical and economic development of the Appalachian Mountain region resources for the benefit of present and future generations. To accomplish this, a better understanding of these hydrologic hazards and the design and implementation of better hydrologic-warning systems are needed.

Other hydrologic-hazard related issues are modifications or revisions to flood-frequency estimates for this region; developing the capability to rapidly identify changes in floodplain areas as a result of changes in land use; and conducting studies of long-term climate records to include the effects of climatic variability into water-resource planning.

An important first step to minimize the consequences of these hydrologic hazards is to analyze the current streamgaging program in the Appalachian Mountain region, add additional streamflow gages, and increase the percentage of stream gages that are equipped to deliver real-time data during floods and other adverse hydrologic conditions. Real-time data collection will include stream stage, stream discharge, precipitation, and selected water-quality characteristics.

Current USGS activities in the Appalachian Mountain region include—collecting, storing, and disseminating basic hydrologic data on the quantity and quality of water, and providing knowledge and expertise to assist various levels of government (Federal, State, and local) in understanding and solving critical local and regional water-resources problems.

The USGS currently operates continuous-recording data collection gages at about 350 streamflow gaging stations, 10 ground-water observation wells, 15 water quality sampling and monitoring sites, and 15 lake and reservoir locations in Alabama, Georgia, North Carolina, South Carolina, Virginia, and West Virginia within the Appalachian Mountain region. Of these about 390 total gaging locations, about 90 percent or 350 locations are real-time data collection and processing sites. USGS historical hydrologic data collection goes back as far as the late 1800's for many of the streamflow gaging stations.

Additional hydrologic data collection of streamflow, water quality, and ground-water resources are needed to adequately monitor and document important information that are becoming vital for critical water resources in the Appalachian Mountain area. These new collection activities will allow the USGS to work with partners from other Federal, State, or local agencies.

Research on Freshwater Mussels (Bivalvia: Unionidae) in Appalachian Streams

Rita F. Villella, David R. Smith, Tim L. King, and David P. Lemarie
U.S. Geological Survey, Leetown Science Center, Aquatic Ecology Laboratory, 1700 Leetown Road, Kearneysville, West Virginia 25430

North America has the richest freshwater mussel fauna in the world, with the greatest diversity concentrated in the eastern United States. However, this diverse fauna are among the most threatened animals in North America with over 70% considered to be endangered, threatened, or of special concern. Though the causes are varied the decline of freshwater mussels can be attributed primarily to degradation and loss of essential habitat. The unique life history of unionids may even contribute to their decline because of their dependence on an obligate fish host for successful reproduction. The introduction of nonindigenous bivalves, specifically *Corbicula fluminea* and more recently *Dreissena polymorpha*, may further the decline leading to local extinctions of native species. The precipitous decline in the molluscan fauna is projected to continue with at least 127 species expected to disappear within the next century. This rate of extinction rivals the estimated loss for tropical rainforest communities. Consequently, the study of freshwater mussel populations is of growing importance for conservation efforts to identify and sustain existing biodiversity. Estimates of population parameters, including life history traits and population density, play a role in research, conservation, and management of freshwater mussels. In 1994 the Leetown Science Center began a freshwater mussel research program focusing on conservation and restoration of native unionids. Studies have begun to address life history and ecology, conservation genetics and systematics, development of rigorous sampling methods for accurate assessment of species distribution and abundance, status and trends surveys, the effects of exotics on mussel ecology, and evaluation of relocation as a management tool through field experimentation. A new research effort will implement rigorous sampling methods to estimate the proportion of a large river system that supports reproducing populations and the frequency distribution of density of endangered species. Results of the river-wide survey will be combined with population modeling to assess site-specific impacts and predict consequences to the viability of the Allegheny River populations. Future research needs must also address conservation efforts at larger spatial scales. Efforts to correlate freshwater mussel distribution and density with site- specific variables have met with little success. Since native mussels spend most of their life burrowed within the river substrate, other environmental factors (e.g., interstitial dissolved oxygen, subsurface water flow) may be influencing mussel population distribution and abundance. The groundwater-surface water ecotone is an active component of stream ecosystems that influences whole-system processes that may play an essential role in structuring mussel populations. Collaborative studies are needed to evaluate whether groundwater influxes influence mussel distribution and population abundances, and to determine whether the relations among landscape features may be important in structuring mussel communities at the basin-wide scale.

Sample Design for Estimating Distribution and Abundance of Freshwater Mussels (Bivalvia: Unionidae) Within a Watershed

Rita F. Villella, David R. Smith, and David P. Lemarie
U.S. Geological Survey, Leetown Science Center, Aquatic Ecology Laboratory, 1700 Leetown Road, Kearneysville, West Virginia 25430

Freshwater mussels are among the most threatened animals in North America. Though the causes are varied the decline of freshwater mussels can be attributed primarily to degradation and loss of essential habitat. The introduction of nonindigenous bivalves, specifically *Corbicula fluminea* and more recently *Dreissena polymorpha*, may further the decline leading to local extinctions of native species. Consequently, the study of freshwater mussel populations is of growing importance for conservation efforts to identify and sustain existing biodiversity. Estimates of population parameters, including population density, play a role in research, conservation, and management of freshwater mussels. However, if the freshwater mussel population in a river is unknown, the question becomes which sampling design is appropriate for describing mussel species and their abundance. Due to the patchy distribution of freshwater mussels at multiple scales, surveys should be designed to sample sites throughout the drainage or watershed to assure accurate assessment of species distribution and abundance. If just a few sites or only sites in relatively close proximity to one another are sampled, the risk is great that densities or richness will be severely under or over estimated. We devised, tested, and implemented a two-phase sampling design to determine the distribution and abundance of freshwater mussel populations in the Cacapon River in West Virginia. The two-phase design provided a framework for combining data from qualitative and quantitative sampling methods. Six species were identified, three of which are rare in the state, including *Lasmigona subviridis* and *Strophitus undulatus*, which were not reported previously from the Cacapon River. River-wide density of freshwater mussels in riffle habitats was estimated to be $0.61/m^2$ with variance = 0.0265. We found important differences in longitudinal distribution and abundance among species. *Elliptio complanata* was present throughout the river but was more abundant, had wider size distributions, and exhibited more recent reproduction within the upper reaches of the river. *Elliptio fisheriana*, second in abundance to *Elliptio complanata*, was abundant only within the lower to middle reaches of the river. Differences in longitudinal distributions have implications to mussel monitoring and conservation. Effective conservation may require protection of contiguous areas within a watershed to account for difference in species distribution and for the importance of dispersal among reaches. Otherwise, protection of only the densest reaches may fail to conserve all at-risk species.

Abundance and Movements of American Eels near Millville Dam, Shenandoah River, West Virginia

Stuart A. Welsh[1] and Steve D. Hammond[2]
[1]U.S. Geological Survey, West Virginia Cooperative Fish and Wildlife Research Unit, POB 6125, Morgantown, West Virginia 26506
[2]West Virginia Cooperative Fish and Wildlife Research Unit, POB 6125, Morgantown, West Virginia 26506

The apparent decline of the American eel population has prompted recent management and conservation concerns. The Atlantic States Marine Fisheries Commission recently listed information and research needs, including needs for knowledge of abundance levels, movements, passage, age and sex of American eels. We are currently conducting a study of American eels in the lower Shenandoah River, West Virginia. The primary study objectives are (1) to quantify seasonal movements of eels by radio telemetry, mark-recapture techniques, and monitoring of fishways on the Millville Dam, and (2) to estimate seasonal abundance of eels near the vicinity of Millville Dam. Secondary objectives are to estimate age, sex, and level of parasitism (swim bladder nematodes) of eels in the lower Shenandoah River drainage.

The Role of Two-Dimensional Direct-Current Resistivity (2D DC-Resistivity) Profiling in a Water-Resource Investigation: Application to Ground Water Exploration and Development in Igneous and Metamorphic Rocks of the Georgia Piedmont/Blue Ridge

Lester J. Williams
U.S. Geological Survey, Georgia District, 3039 Amwiler Road, Suite 130, Atlanta, Georgia 30360

Two-dimensional direct-current resistivity (2D DC-resistivity) profiling can be used in water-resource investigations to help to detect water-bearing zones in bedrock. In a cooperative project between the U.S. Geological Survey and the City of Lawrenceville, Gwinnett County, Georgia, resistivity profiling was conducted to help explore for transmissive water-bearing zones in igneous and metamorphic rock aquifers before test drilling. Results from surveys were used to site and drill several test wells. At one test site, resistivity profiling revealed water-bearing zones to a depth of 80 feet that were encountered in the test drilling.

A primary consideration in using resistivity profiling in water-resource investigations is the depth to which a resistivity profile can be reliably produced. In Lawrenceville, most of the high-yielding wells produced from transmissive zones at depths between 200 and 300 feet—well below the general practical depths that can be explored with resistivity profiling in this area. Resistivity imaging was generally conducted to a maximum depth of 180 feet using a dipole-dipole array of 83 electrodes spaced 13 feet apart (total array 1,089 feet long). An electrode spacing of more than 13 feet allows for a greater depth of penetration but with less resolution. The depth limitation of this technique and the resolution needed for discrete fracture zones often observed in Lawrenceville prevented the use of resistivity profiling for water-resource evaluations in the most productive water-bearing zones.

An equally important consideration in applying resistivity profiling in igneous and metamorphic rocks is correlating the electrical image to geologic features at the test site such as thickness of saprolite and resistivities of different rock types. Site-specific geologic maps were constructed for each area and structural measurements were taken. To improve interpretation of the resistivity data in Lawrenceville, profiling was conducted at a high-yielding well site and low-yielding well site. This provided valuable information on the effects of different arrays and electrode spacings required to provide adequate resolution of water-bearing fracture zones. Borehole electrical resistivity logs also provided direct measurements of rock resistivities in fractured- and unfractured-rock. This information is needed to develop reasonable interpretations of the resistivity data collected.

In Lawrenceville, fracture zones in the igneous and metamorphic rock aquifers are normally associated with a zone of low apparent resistivity. In almost every case, resistivity profiling allowed the imaging of shallow water-bearing zones but did not distinguish individual fractures in the bedrock.

If electrical resistivity profiling is used in water-resource investigations in igneous and metamorphic rock aquifers, every effort must be taken to correlate these data to geologic features at the site. Depth limitations and resolution of the target zone should be major considerations when applying this technique. If the target zone is deeper than what can be imaged by the system then this technique may not benefit the exploration effort. Electrical imaging techniques should also be used in conjunction with a good understanding of the site-specific geology so these data can be interpreted correctly.

Assessing Vegetation Community Composition in Relation to Environmental Gradients in Shenandoah National Park, Virginia

John Young[1], Dean Walton[2], Gary Fleming[2], and Dave Morton[1]
[1] U.S. Geological Survey, Leetown Science Center, Leetown, WV
[2] Virginia Department of Conservation and Recreation, Natural Heritage Program, Richmond, VA

A number of researchers have examined vegetation distribution in relation to environmental gradients derived from digital elevation data. Important gradients that recur in these studies are, slope direction, slope position, slope shape, moisture, light, and (less commonly) rock type, and elevation. We developed GIS-based environmental gradient models in an effort to accurately describe and map vegetation community composition in Shenandoah National Park, Virginia. The gradient models produced for this study were used to stratify the park into "ecological land units" and were used to locate representative field vegetation sampling plots. The gradient models produced will also help to guide remote sensing investigations, and will form the basis of GIS-based predictive modeling of vegetation distribution in future efforts. Aside from providing a map for National Park Service managers, this project will examine vegetation distribution patterns resulting from response to environmental gradients in contrast to human- and natural disturbance induced distribution patterns. This poster will discuss the derivation of environmental gradient models for Shenandoah National Park and the goals and progress to date on this research.

ADDITIONAL ABSTRACTS

Earthquake Hazard in the Appalachian Region
Joan Gomberg and Eugene Schweig

An Integrated Geographic Database and Web Site
Anthony V. Herr

Virginia Tech Cooperative Park Studies Unit
Jeffrey L. Marion

Restoration of a Native Brook Trout Fishery to the Upper Shavers Fork, a Large, High-Elevation Watershed in West Virginia
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Water Quality in the Coal Mining Areas of the Appalachian Plateau
Steve McAuley

Mesohabitat Use of Threatened Hemlock Forests by Breeding Birds of the Delaware Water Gap National Recreation Area
Robert M. Ross

Landscape Determinants of Nonindigenous Fish Invasions
Robert M. Ross, William A. Lellis, Randy M. Bennett, and Connie S. Johnson

On-Going Wildlife Research in the Southern Appalachians
Ted Simons

Influence of Water Quality, Stream Gradient, and Flooding on Fish Distributions in the New River Gorge National River
Stuart A. Welsh and David I. Wellman

Earthquake Hazard in the Appalachian Region

Joan Gomberg and Eugene Schweig
US Geological Survey, Central Region Geologic Hazards Team
3876 Central Ave., Suite 2
Memphis, TN 38152-3050

The Appalachians host the Southern Appalachian seismic zone (SASZ), extending from Alabama to Virginia. The most active portion of the SASZ during the past 15 years, and perhaps longer, extends ~300 km from northwestern Georgia through east Tennessee, and is referred to as the East Tennessee seismic zone (ETSZ). The ETSZ is the second most active seismic region in the eastern U.S. (*Powell, et al.*, 1994) (Fig. 1). On average, a few earthquakes of magnitude ~3.0 occur in the SASZ annually (the number of smaller magnitude earthquakes increases approximately tenfold for each magnitude unit decrease). The most seismically active region in the eastern US is the New Madrid seismic zone (NMSZ).

Most of the seismicity in the SASZ is attributed to reactivation of Precambrian age faults in the crystalline basement rocks buried beneath younger sedimentary rocks. The tectonic stress regime is thought to be essentially the same for the SASZ and NMSZ; the maximum stress is oriented nearly horizontal and trends east-northeast to west-southwest.

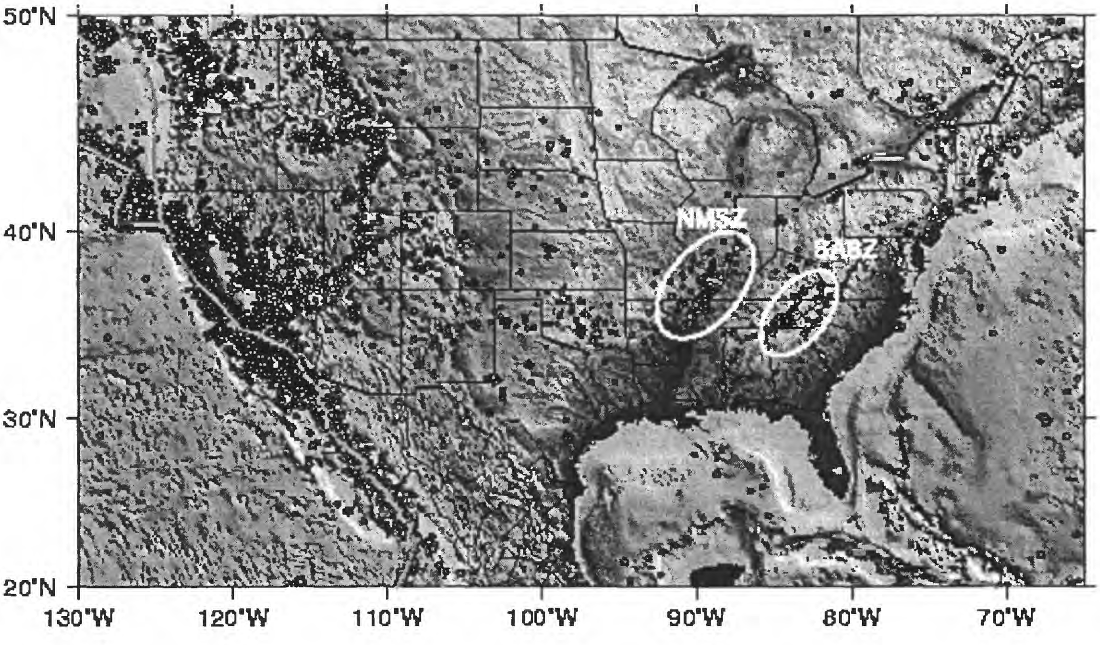

Figure 1. Earthquakes in the United States from 1977 to 1997 (from the USGS Natl. Earthquake Information Center). White ovals show approximate areas comprising the Southern Appalachian seismic zone (SASZ) and New Madrid seismic zone (NMSZ).

Assessing seismic hazard in the SASZ is made difficult by the fact that the zone has not experienced any earthquakes with magnitudes of 6.0 or greater in historic times. This does not mean that the region is not capable of producing a larger event, but simply that our observation time is much shorter than the time-scales over which large earthquakes occur. The largest known earthquake in the SASZ was the Giles County, Virginia earthquake of 1897, which had an estimated magnitude of 5.8. The largest known earthquake in the ETSZ was the magnitude 4.6, 1973 Maryville, Tennessee earthquake. Earthquake faulting in the ETSZ, at least as inferred from small, instrumentally recorded earthquakes, appears to occur between 5-26 km depth on steeply dipping strike-slip faults (*Vlahovic and Powell*, 2001).

Most of the SASZ region is covered by consolidated Paleozoic sedimentary rocks or crystalline rocks of Precambrian age. The scarcity of easily deformable rocks and sediments in the SASZ, rugged topography, and dense vegetation make seismic hazard assessment challenging, particularly the identification of prehistoric earthquakes from paleoseismic studies. To date, only a few such studies have been conducted and these produced no conclusive evidence of damaging prehistoric earthquakes. Unlike the NMSZ, however, liquefaction is not a significant earthquake-related hazard.

Earthquake monitoring has been the USGS's primary activity related to earthquake hazards in the Appalachians. The External Program of the USGS Earthquake Hazards Program has funded cooperative agreements to universities for the operations of several permanent monitoring networks in the SASZ. For the past two years much of the monitoring in the SASZ has been combined with network operations in the NMSZ, and all data acquisition and most processing efforts have been linked (Fig. 2) as part of the development of the US's Advanced National Seismic System (ANSS).

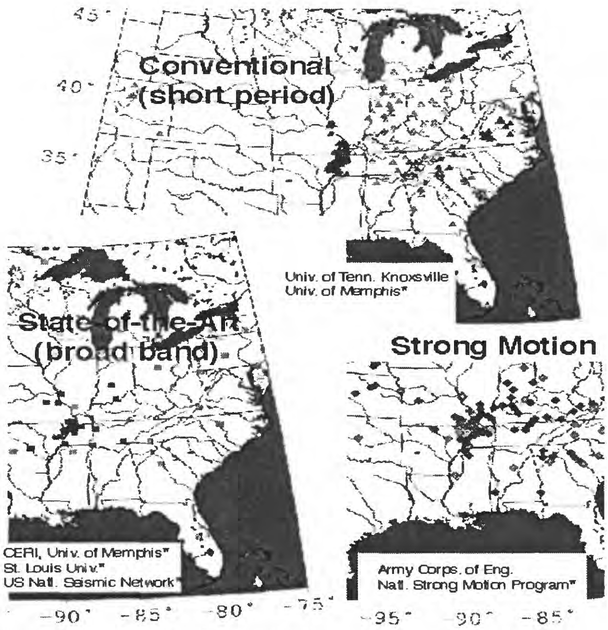

Figure 2. Symbols show locations of seismic monitoring stations of various types. Conventional stations (top) only record earthquakes on-scale in a very limited size range and in a limited spectral frequency band. More sophisticated broad band instruments (bottom left) record over a larger magnitude and frequency range. Strong motion stations (bottom right) are designed to record only the very large motions very close to the earthquake source and generally do not detect small earthquakes. The institutions responsible for monitoring are listed with asterisks denoting those supported by the USGS.

The Tennessee Valley Authority also monitors earthquakes in the SASZ and participates in data exchange in the region. The SASZ is part of the Mid-America region of the ANSS. One benefit of the ANSS has been unified reporting of earthquakes in near real-time and standardized dissemination of this information to the public (Fig. 3).

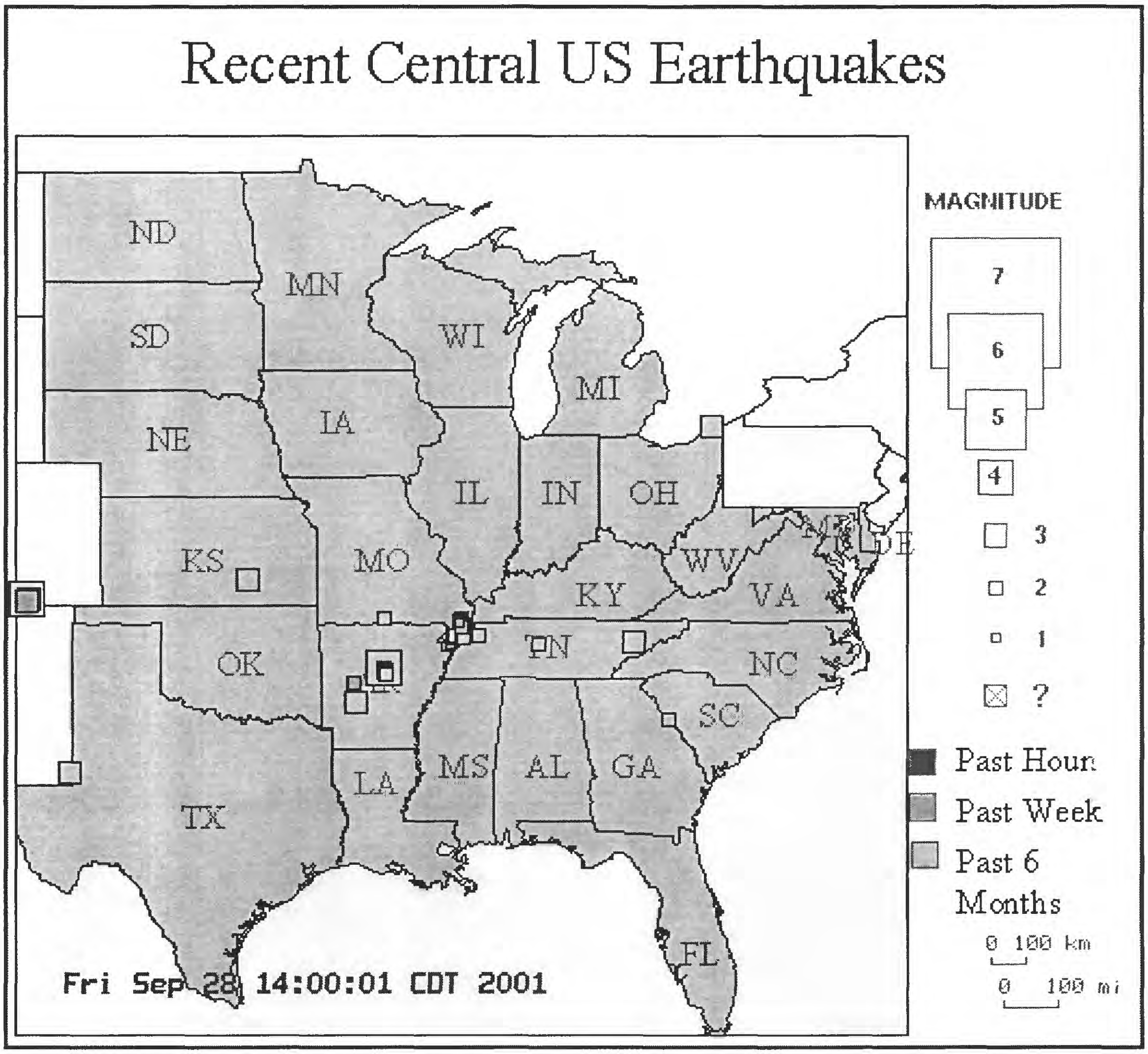

Figure 3. Example of how earthquake occurrence is reported in near real-time over the Web for the entire central and southeastern US. Similar pages are produced for other regions of the country, all using software developed by the USGS. The Web address is http://folkworm.ceri.memphis.edu/recenteqs/.

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Vlahovic, G. and C. A. Powell, A Three-dimensional P-wave tomographic image for the Eastern Tennessee Seismic Zone, Seismological Research Letters, submitted, 2001.

An Integrated Geographic Database and Web Site

Anthony V. Herr
USGS ER Geography, 521 National Center, Reston, Virginia 20192

An integrated database of information, including project data and reports, is an important component of an integrated science program. To make these data easily available and useable is part of the mission of the USGS. A Web-accessible database is a necessary step to ensure ease of use for scientists and the general public. Datasets would have formats common to many geographic information systems (GIS) mapping packages and analytical software packages. The proposed database would include base geographic, hydrologic and biologic information and other datasets, such as land cover, hazards information and population dynamics. These data would be organized by focus area to facilitate communications and research investigations. Data would be available either by direct download or through FTP from a dedicated Web site, which would be modeled after the South Florida Information Access site (SOFIA, http://sofia.usgs.gov) and would incorporate many of the ideas from the Southern Appalachian Information Node (SAIN). The goals of this activity complement many of the outreach and technical goals of the SAIN. Eastern Region Geography will develop this Web site and the database over the next 2 years if appropriate funding can be obtained.

Virginia Tech Cooperative Park Studies Unit

Jeffrey L. Marion
Unit Leader and Scientist, Patuxent Wildlife Research Center, Virginia Tech Cooperative Park Studies Unit, 304 Cheatham Hall (0324), Blacksburg, VA 24060
jmarion@vt.edu

The Virginia Tech Cooperative Park Studies Unit is a field station of the Patuxent Wildlife Research Center and is affiliated with the Department of Forestry Recreation Resource Management Program, College of Natural Resources. The focus of this unit is on the field of recreation ecology, defined as research and monitoring to identify, document and understand visitor-related impacts to protected area resources. An enhanced understanding of recreational impacts and their relationships with use-related, environmental, and managerial factors can aid managers in defining acceptable limits of change and in decision making necessary to balancing recreational uses with their associated resource impacts.

Unit research has been conducted at numerous sites within the Appalachian Mountains Region, including Great Smoky Mountains and Shenandoah National Parks, New River Gorge National River (and 4 other WV rivers), Delaware Water Gap National Recreation Area, and Upper Delaware Scenic and Recreational River. These studies have involved investigations of tramping impacts to soils and vegetation associated with hiking activities (trail-related), day-use (picnic sites, river rafting), and overnight use (campsites). Over the past two years site visits and management consultations involving 16 high use and impact shelter/camping areas along the Appalachian Trail have been conducted. Case studies have been prepared and research and monitoring to evaluate the effectiveness of implemented management responses will soon be initiated. Similar work is underway at Shenandoah NP to evaluate a new set of camping management options implemented at the park in 2000.

Other relevant unit work includes research and technical assistance in carrying capacity decision frameworks, including identification of prescriptive management objectives, selection of resource indicators and standards, and development of impact monitoring protocols. Limited work has also been conducted to examine visitor impacts to wildlife, including an extensive review of monitoring methods.

Restoration of a Native Brook Trout Fishery to the Upper Shavers Fork, a Large, High-Elevation Watershed in West Virginia

Patricia M. Mazik[1] and J. Todd Petty[2]
[1]USGS/BRD, WV Cooperative Fish and Wildlife Research Unit, West Virginia University, Division of Forestry, 322 Percival Hall, Morgantown, WV 26506-6125, phone: 304/293-3794; email: pmazik@wvu.edu
[2]West Virginia University, Division of Forestry, 322 Percival Hall, Morgantown, WV 26506-6125, phone: 304/293-3794; email: jtpetty@wvu.edu

A series of studies were designed to assess the feasibility of restoring a native brook trout (*Salvelinus fontinalis*) fishery to the upper Shavers Fork in West Virginia. These studies included: basin-wide assessment of water and habitat quality, quantification of stream ecosystem processes along a river continuum, radiotelemetry of brook trout movements and habitat use, spatial structure and dynamics of trout populations in the Shavers Fork mainstem and associated tributaries, and applying habitat selection theory to predict trout population response to watershed management approaches. Our results indicate that the future quality of the fishery is critically dependent on the success of proposed watershed restoration actions, which include limestone additions to acidified tributaries and restructuring of the mainstem channel to increase habitat complexity.

Water Quality in the Coal Mining Areas of the Appalachian Plateau

Steve McAuley
U.S. Geological Survey, 1000 Church Hill Road, Pittsburgh, Pa. 15205

Water quality of the surface and ground water in coal mining areas of the Allegheny and Monongahela River Basins (ALMN) was assessed during 1996-98 as part of the National Water Quality Assessment (NAWQA) program of the U. S. Geological Survey.

Although improvements in water quality have resulted from efforts initiated by government agencies, concerned citizens, and coal companies, coal mining remains the largest single factor affecting water quality in a large part of the ALMN. New sources of highly acidic and metal-laden discharges are rarely seen today, but surface and ground water leaving coal mined areas does differ from surface and ground water in unmined areas, particularly constituents such as sulfate. Sulfate yields in 8 mined basins sampled were on average 5 times greater than sulfate yields in 3 unmined basins sampled. Both numbers of fish and number of fish species were greater in unmined basins compared to mined basins. In basins where sulfate was greater than background (about 21 mg/L in ALMN areas that are unmined) aquatic invertebrates showed decreased diversity.

In 1998, a regional assessment to define water quality in coal mining regions of both the ALMN and the Kanawha-New River Basin (KANA) was added to the NAWQA program. The 1998 regional assessment included sampling 178 sites for surface water chemistry, 61 sites for invertebrates, and 83 wells for ground water chemistry. Mined sites were compared to unmined sites. Surface water sites sampled in 1998 were compared to chemistry from the same sites sampled in 1979. The median pH increased and the total iron and total manganese concentrations decreased in mined basins between 1979-81 and 1998, reflecting improved water quality during the last two decades. Dissolved iron, manganese, and aluminum concentrations in mined areas exceeded water quality standards much more often in mined basins than in unmined basins. Sulfate, an unregulated constituent in mined basins also often exceeded sulfate concentrations in unmined basins. Invertebrate communities tended to be more impaired in mined basins than in minimally altered basins and unmined basins. Pollution tolerant species were more likely to be present in mined basins compared to unmined basins, whereas pollution-sensitive taxa were few or absent in heavily mined basins. Both an increased sulfate concentration and a decline in some aquatic insect populations were related to coal production. Ground water from wells located downgradient from surface coal mines that completed reclamation efforts exceeded water quality standards for sulfate, iron, manganese, and aluminum much more frequently than ground water in unmined areas.

Mesohabitat Use of Threatened Hemlock Forests by Breeding Birds of the Delaware Water Gap National Recreation Area

Robert M. Ross
United States Geological Survey, Leetown Science Center, Northern Appalachian Research Laboratory, R. D. #4 Box 63, Wellsboro, Pennsylvania 16901

To assess avian biodiversity, mesohabitat relations, and the risk of loss of species diversity with declining hemlock forests in Appalachian park lands, 80 10-min point counts of breeding birds were conducted in June 2000 on four forest-terrain types previously sampled in the Delaware Water Gap National Recreation Area (DEWA) for aquatic biota: hemlock and hardwood benches and ravines. Point centers were established randomly within sample units, ground truthed with the aid of Global Positioning System technology, and moved if necessary to avoid habitat edge. Point-count radii were limited to 50 m to minimize differential species detection rates, and all counts were conducted between 0530 and 1000 hours in good weather conditions. Mesohabitat sensitivity was calculated as $(D_b - H_b) + (D_r - H_r)$ for forest type and as $(B_d - R_d) + (B_h - R_h)$ for terrain type, where D, H, B, and R are proportion of points where the species occurred in hardwood (deciduous), hemlock, bench, and ravine habitats, respectively, and d, h, b, and r qualify specific mesohabitats.

We found species richness in hemlock stands (means of 24 and 19 in benches and ravines) to be less than that of hardwood stands (35 and 29), with ravines of both forest types generally supporting fewer species than benches. Territories were also denser in hardwood (9.5 and 7.2 per point) than hemlock (5.8 and 4.7) stands, with somewhat lower densities in ravine terrains than benches in each case. Species most sensitive to forest type were black-throated green warbler (*Dendroica virens*), American redstart (*Setophaga ruticilla*), red-eyed vireo (*Vireo olivaceus*), Blackburnian warbler (*Dendroica fusca*), blue-headed vireo (*Vireo solitarius*), Acadian flycatcher (*Empidonax virescens*), scarlet tanager (*Piranga olivacea*), eastern wood-pewee (*Contopus virens*), and wood thrush (*Hylocichla mustelina*), while those most sensitive to terrain type were American redstart, red-eyed vireo, ovenbird (*Seiurus aurocapillus*), blue-headed vireo, veery (*Catharus fuscescens*), and Blackburnian warbler. Of these only four species showed strong preference for hemlock over hardwood habitat: black-throated green warbler, Blackburnian warbler, blue-headed vireo, and Acadian flycatcher. Of these four forest-type specialists, only two, Blackburnian warbler and blue-headed vireo, showed strong preference for a particular terrain type, the ravine mesohabitat. Thus breeding bird data from DEWA forests indicate that four insectivorous neotropical species, Acadian flycatcher, blue-headed vireo, black-throated green warbler, and Blackburnian warbler, are essentially obligate hemlock-associated species at risk should adelgid-mediated hemlock decline continue in park lands and similar forests of the mid-Atlantic east slope. Two of these, the blue-headed vireo and Blackburnian warbler, appear to specialize in ravine mesohabitats of hemlock stands, the vireo a low-to-mid canopy species, the warbler a mid-to-upper canopy forager.

Landscape Determinants of Nonindigenous Fish Invasions

Robert M. Ross, William A. Lellis, Randy M. Bennett, and Connie S. Johnson
United States Geological Survey, Leetown Science Center, Northern Appalachian Research Laboratory, Rural Delivery 4 Box 63, Wellsboro, Pennsylvania 16901, (e-mail: rossr@usgs.gov)

Much has been written about the influence of exotic or nonindigenous species on natural habitats and communities of organisms, but little is known of the physical or biological conditions that lead to successful invasion of native habitats and communities by exotics. We studied invasivity factors in headwater streams of the Susquehanna River West Branch, which drains portions of the northern Appalachian Plateau. A replicated (two major tributaries) 3 X 3 factorial design was used to determine landscape effects of size (stream order) and quality (land use) on abiotic (physical and chemical) and biotic (fish community structure and function) stream attributes. Seven (21%) of 34 fish species (brown trout, common carp, mimic shiner, bluegill, smallmouth bass, fantail darter, and banded darter) collected in the 18 streams sampled were nonindigenous to the basin. Watershed size (stream orders 1, 3, and 5) significantly affected stream geomorphologic and habitat variables (gradient, width, depth, current velocity, diel water temperature, bank overhang, canopy cover, and woody debris density) but not water-quality variables, while land use in watersheds (conservation, mining, and agriculture) significantly affected measured water-quality variables (alkalinity and concentrations of manganese, calcium, chloride, nitrate, and total dissolved solids) but not stream physical or habitat quality. Both watershed size and land use affected fish-community variables such as presence of particular species, species density, species diversity, tolerance diversity, and mean fish size, but in both cases the effect was transparent to native-origin status of fish species. No relationships were found between occurrence of nonindigenous species in watersheds and trophic structure or functional diversity. Therefore, the hypothesis that reduced species diversity increases vulnerability to nonindigenous species was not supported. However, the spatial variation associated with both water-quality and habitat-quality factors was greater in streams with mixed (those with nonindigenous species) than with exclusively native assemblages. These findings suggest that the mechanism for successful invasion by nonindigenous or exotic species is through change in water or habitat quality associated with human or natural disturbances, such as agriculture and mining activities in watersheds. Biotic factors appear to play no or a lesser role in the invasibility of northern Appalachian lotic systems.

On-Going Wildlife Research in the Southern Appalachians

Ted Simons
USGS-BRD, North Carolina Cooperative Fish and Wildlife Research Unit, Department of Zoology, North Carolina State University, Raleigh, NC 27695

Six research projects underway at the USGS Cooperative Fish and Wildlife Research Unit at NC State University are examining questions related to the ecology of birds and salamanders in the southern Appalachians. They are:

Ecology and conservation of Neotropical migrants in the southern Appalachians

This study will serve as the basis of Ph.D. thesis at NC State University. It seeks to develop an ecosystem level approach to understanding the conservation needs of Neotropical migratory birds in the southern Appalachians. Great Smoky Mountains National Park (GRSM) is being established as a control site for comparing trends in the distribution and abundance of forest bird populations compared with those from more disturbed habitats in the southern Appalachians. This study will contribute to an evaluation of the effects of land use practices on the diversity and abundance of these birds at a regional scale. The study will:

1. Produce accurate distribution maps of breeding bird species in the Park.
2. Project how large-scale changes, such as forest tree loss due to exotic diseases, air pollution, climate change, or the invasion of Brown-headed Cowbirds or other exotic species, may affect the breeding bird community.
3. Predict the degree to which site disturbances due to development or management may affect particular breeding bird species.
4. Estimate the importance of the Park as a regional population source for declining bird species.
5. Incorporate project data and protocols into the Park's long-term resource monitoring program.

The effects of landscape pattern, core areas, and forest management practices on avian communities in the southern Appalachians

This will serve as the basis of an M.S. thesis at NC State University. The study expands an on-going avian community study in Great Smoky Mountains National Park (GRSM) to include U.S. Forest Service lands adjacent to the Park. GRSM will be used as a control site to examine breeding populations of forest birds in adjacent, managed forests. Together, these studies seek to develop an ecosystem level approach to understanding the conservation needs of breeding birds in the southern Appalachians. A total of 1,376 independent point locations have been censused for breeding birds. Data are being analyzed to determine the relative importance of local versus landscape scale habitat features in predicting the spatial distribution of different bird species.

Determinants of forest songbird nesting success in the southern Appalachians

This study will serve as the basis of a Ph.D. thesis at NC State University. Analysis of 30 years of North American breeding bird survey data indicates that populations of many species have undergone significant declines over the past decade. Reduced nesting success associated with high rates of nest predation in disturbed forest ecosystems has been identified as a major factor in the decline of these populations. The protected natural areas of the Southern Appalachians provide a unique opportunity to address conservation issues for these birds at an ecosystem level. The study is examining the factors influencing nesting success in forest songbird populations in Great Smoky Mountains National Park and adjacent National Forests and wilderness areas. Results of this research are expected to make a significant contribution to the conservation and management of forest songbird populations in the southern Appalachians.

Assessing the diversity and habitat associations of salamanders in Great Smoky Mountains National Park

This study will serve as the basis of an M.S. thesis at NC State University. The study is measuring the diversity, abundance, and habitat associations of salamanders in the Mt. LeConte quadrangle of Great Smoky Mountains National Park to determine if existing data and protocols developed for long-term breeding bird and vegetation monitoring can be applied to salamanders. Because the habitat associations of salamanders are not well understood, and because salamanders and birds use their habitats on different temporal and spatial scales, the extent to which monitoring programs for these two groups can compliment one another is currently unknown. While there is considerable interest in the degree to which one group of species can indicate habitat conditions for another, to date the concept has received little critical testing. The study will contribute to the development of salamander population monitoring protocols that can be incorporated into the Park's long term natural resource monitoring program.

Evaluation of salamander habitat associations and population monitoring techniques in Great Smoky Mountains National Park

This study will serve as the basis of a Ph.D. thesis at NC State University. It critically examines the relationship between commonly used amphibian abundance indices and estimated true population size. Salamander population size is estimated using capture-recapture, depletion experiments, and a total removal technique. Results are compared to count data from the relative abundance indices to determine the nature of the relationship between count data and population size, and to establish whether observability remains constant over time and space. Constant observability over both time and space are the two key assumptions that need to be met before count indices can be used to infer changes in salamander populations over time, or differences in abundance between locations or habitats.

Statistical inference from count surveys

This study is a collaboration with Dr. George Farnsworth at the University of Houston and colleagues Jim Nichols, Jim Hines, and John Sauer at the Patuxent Wildlife Research Center. We have developed a removal model to estimate detection probability during point count surveys for breeding birds. The model assumes the main factor influencing detection during point counts is the singing frequency of birds. This method for estimating detectability during point count surveys offers a promising new approach to using count data to address questions of abundance, density, and population trends of birds.

Influence of Water Quality, Stream Gradient, and Flooding on Fish Distributions in the New River Gorge National River

Stuart A. Welsh[1] and David I. Wellman[2]
[1]U.S. Geological Survey, West Virginia Cooperative Fish and Wildlife Research Unit, POB 6125, Morgantown, West Virginia 26506
[2]West Virginia Cooperative Fish and Wildlife Research Unit, POB 6125, Morgantown, West Virginia 26506

Fish distributions and the species composition of fish communities are influenced by watershed/stream characteristics, catastrophic events, and nonnative species. Currently we are studying the distributions and composition of fishes in the major perennial tributaries of the New River within the New River Gorge National River. Specifically, we are examining watershed/stream characteristics and nonnative species and their association with fish distributions, as well as the affect of recent flood events.