RADON IN GROUND WATER OF THE LOWER SUSQUEHANNA AND POTOMAC RIVER BASINS

by Bruce D. Lindsey and Scott W. Ator

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Abstract

Ground-water samples collected from 267 wells were analyzed for radon as part of a water-quality reconnaissance of subunits of the Lower Susquehanna and Potomac River Basins conducted by the United States Geological Survey (USGS) as part of the National Water-Quality Assessment (NAWQA) program. Radon is a product of the radioactive decay of uranium. Airborne radon has been cited by the Surgeon General of the United States as the second-leading cause of lung cancer and the United States Environmental Protection Agency (USEPA) has identified ground-water supplies as possible contributing sources of indoor radon. Eighty percent of ground-water samples collected for this study were found to contain radon at activities greater than 300 pCi/L (picocuries per liter), the USEPA's proposed Maximum Contaminant Level for radon in drinking water, and 31 percent of samples contained radon at activities greater than 1,000 pCi/L.

The 10 subunits where samples were collected were grouped into three classes - median ground-water radon activity less than 300 pCi/L, between 300 pCi/L and 1,000 pCi/L, and greater than 1,000 pCi/L. Subunits underlain by igneous and metamorphic rocks of the Piedmont Physiographic Province typically have the highest median ground-water radon activities (greater than 1,000 pCi/L); although there is a large variation in radon activities within most of the subunits. Lower median radon activities (between 300 pCi/L and 1,000 pCi/L) were found in ground water in subunits underlain by limestone and dolomite. Of three subunits underlain by sandstone and shale, one fell into each of the three radon-activity classes. The large variability within these subunits may be attributed to the fact that the uranium content of sandstone and shale is related to the uranium content of the sediments from which they formed.

WHAT IS RADON?

Radon is a naturally occurring, colorless, odorless gas that is soluble in water. It is radioactive, which means that it breaks down - or "decays" - to form other elements. The rate of radon's radioactive decay is defined by its half-life, which is the time required for one half of any amount of the element to break down. The half-life of radon is 3.8 days (Hem, 1985).

The source of radon is the radioactive decay of uranium. Therefore, higher radon amounts are commonly detected in areas underlain by granites and similar rocks that usually contain more uranium than do other rock types (Faure, 1986). Radon moves from its source in rocks and soils through voids and fractures. It can enter buildings as a gas through foundation cracks or dissolve in the ground water and be carried to water-supply wells.

The amount of radon in air or water commonly is reported in terms of activity with units of picocuries per liter of air or water. An activity of 1 pCi/L (picocuries per liter) is about equal to the decay of two atoms of radon per minute in each liter of air or water (Otton, 1992). This report will refer to picocuries per liter as the radon concentration.

WHY STUDY RADON?

Exposure to radon has been recognized as a health risk, primarily as a cause of lung cancer. A study of miners found that inhaling the decay products of radon increases the chances of lung cancer (Robillard and others, 1991). The Surgeon General of the United States has recognized radon gas as being second only to cigarette smoking as a cause of lung cancer (U.S. Environmental Protection Agency, 1992). Radon gas can cause lung cancer if inhaled because the products of its decay can accumulate in the lungs and damage lung tissue. As it decays, radon produces several short-lived elements that are also radioactive. Radon and these decay-products emit alpha particles that, because of their high energy, can damage lung tissue (Brooks, 1988). Although most radon is exhaled before it can do much damage (Hurlburt, 1989), the decay-products can remain trapped in the respiratory system, attached to dust, smoke, and other fine particles from the air. Eventually, the concentration of these radioactive elements in constant, close contact with lung tissue can cause cancer (Zapecza and Szabo, 1988).

A recent study found that cancer occurrences increase as the amount of radon in home water increases (Mose and others, 1990). Other studies have also determined that there is an increased health risk from drinking water with high concentrations of radon (Crawford-Brown, 1990); however, most research is focused on the dangers of inhaling radon gas and its decay products. The U.S. Environmental Protection Agency (USEPA) has not established a Maximum Contaminant Level (MCL) for radon in drinking water; however, the proposed MCL is 300 pCi/L (U.S. Environmental Protection Agency, 1994).

Radon gas commonly enters the air in homes through the basement. Ground water can carry additional radon into homes and other buildings, creating a health risk. Dissolved radon is easily released into the air when the water is used for showering, cleaning, and other everyday purposes. The radon, therefore, commonly is released in close proximity to those using the water (fig. 1). Also, in homes built with better insulation and better seals

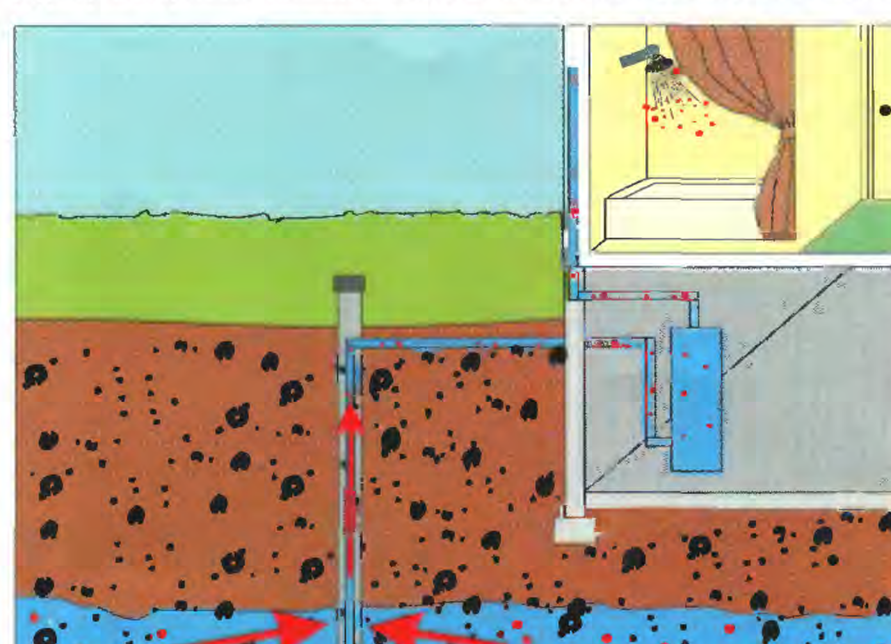

Figure 1. Radon entering a home through a water system (modified from Otton, 1992).

on windows and doors, radon has less chance to be ventilated to the outside and can become concentrated to dangerous levels in indoor air. Most radon escapes from the water at the faucet, leaving little in the water itself (Hurlburt, 1989). The radon that escapes from the water adds to the radon that enters the home through the basement, and in some cases the water contributes a large portion of the radon that is present in a home.

Water-borne radon is commonly a concern only for those who use wells for their water supply. Because of its short half-life, radon in public water supplies usually decays to low concentrations before the water is delivered to users, especially if the water has been treated. Also, public suppliers often use surface-water supplies, which generally have very low radon concentrations (Zapecza and Szabo, 1988).

WHERE DID WE LOOK?

This investigation is part of the National Water-Quality Assessment (NAWQA) of water resources in 60 major river basins throughout the United States (Gilliom and others, 1995). During 1993-95, NAWQA projects in the Lower Susquehanna and Potomac River Basins conducted studies to determine the effects of land use on shallow ground-water quality. Water samples collected from wells in the study areas were analyzed for both man-made substances and naturally occurring substances, such as radon. The spatial distribution and density of sampling sites are not sufficient for a detailed study of radon. However, general conclusions about the regional distribution of radon in ground water can be made on the basis of these reconnaissance studies.

The study area includes the District of Columbia and parts of Maryland, Pennsylvania, Virginia, and West Virginia (fig. 2). Ground-water-quality assessments were conducted in subunits in the two basins that were defined on the basis of the geology (type of bedrock) and the physiographic province (an area of similar elevation, topography, and physical features). The three general types of bedrock in this area are (1) limestone and dolomite, (2) sandstone and shale, and (3) igneous or metamorphic rocks, such as granite, schist, and quartzite. The physiographic provinces studied include the Piedmont and the Ridge and Valley (table 1).

Division of the study area on the basis of bedrock type and the physiographic provinces and sections resulted in seven areas where radon in ground water was studied. Three of these areas were further subdivided on the basis of river drainage basin. Within these 10 subunits, 267 ground-water samples were collected from wells and analyzed for dissolved radon (table 1) (fig. 2). Because sampling was conducted independently in each basin, the subunits generally do not cross the basin divide. The Piedmont and Appalachian Mountain limestone subunits include those areas in both basins because both contained too little area in the Potomac River Basin to be studied separately. The areas of igneous and metamorphic bedrock are termed "crystalline" in the names of the subunits (table 1). The Piedmont sandstone and shale subunit, which also contains abundant diabase, is commonly called the "Triassic Lowlands." The Western Piedmont crystalline subunit was sampled as a part of the Piedmont subunit as defined in the Potomac NAWQA study design (Blomquist and others, in press); however, this subunit was considered separately for the radon study. The study design did not allow for sampling in every physiographic province or subunit.

The wells selected for sampling had to meet certain location and construction criteria and have similar characteristics, including type, depth, and age. All wells sampled were constructed as open boreholes, drilled and completed with casing typically set a few feet into the bedrock. Wells were to have a maximum depth of 200 feet and a maximum age of 20 years. A few of the wells sampled exceeded the age and depth criteria.

WHAT DID WE FIND?

The ground-water samples were analyzed at the USGS National Water-Quality Laboratory in Arvada, Colo. The results were analyzed to determine general patterns in the concentration of radon among the 10 subunits. The amount of radon in ground water from each subunit is highly variable, so the subunits were classified on the basis of the median concentration for the subunit. The median is the concentration at which half of the samples have a lower concentration and half have a higher concentration. On the basis of graphical and statistical analyses, 300 pCi/L and 1,000 pCi/L were chosen as boundary values for grouping subunits by their median radon concentrations. The use

Table 1. *Subunits for assessment of radon in ground water, Lower Susquehanna and Potomac River Basins*

Physiographic Province	PIEDMONT					RIDGE AND VALLEY				
Physiographic Section	LOWLAND		UPLAND			APPALACHIAN MOUNTAIN			GREAT VALLEY	
Bedrock type	Limestone and dolomite	Sandstone and shale	Igneous and metamorphic			Limestone and dolomite	Sandstone and shale		Limestone and dolomite	
Subunit name	Piedmont limestone	Piedmont sandstone and shale	Piedmont crystalline		Western Piedmont crystalline[1]	Appalachian Mountain limestone	Appalachian Mountain sandstone and shale		Great Valley limestone	
River basin	Susquehanna	Potomac	Susquehanna	Potomac	Potomac	Susquehanna	Susquehanna	Potomac	Susquehanna	Potomac
Number of wells sampled	[2]31	23	28	18	7	[3]33	29	23	48	27

[1] The Western Piedmont Crystalline subunit was separated from the rest of the Piedmont Crystalline subunit for this report because of geologic differences important to the occurrence of radon. Some recent maps have included this area as part of the Blue Ridge Province.

[2] This subunit includes one sample collected in the Potomac River Basin.

[3] This subunit includes three samples collected in the Potomac River Basin.

WHY IS RADON HIGHER IN SOME AREAS THAN IN OTHERS?

An important factor affecting the amount of radon in ground water in the Lower Susquehanna and Potomac River Basins is the predominant underlying rock type. Many factors that affect the formation and movement of radon in the ground - the uranium content, grain size, and permeability of the host rock and the nature and extent of fracturing in the host rock (Otton, 1992) - are functions of rock type. Climatic factors such as barometric pressure and rainfall can affect the concentration of radon in ground water over time. These factors can be difficult to evaluate in a regional study, however, because of the overwhelming effects of other variables on radon concentration.

Radon distribution in ground water in those subunits of the Lower Susquehanna and Potomac River Basins underlain by igneous and metamorphic rocks and limestone follows a general geographical pattern related to rock type. Except for the Western Piedmont subunit, median ground-water radon concentrations are higher in subunits underlain by igneous and metamorphic rocks than in those underlain by limestone (fig. 3). Most igneous and metamorphic rocks in the Piedmont are of predominantly granitic composition. These rocks contain higher concentrations of uranium, on average, than do limestones (Faure, 1986). The median ground-water radon concentration in the Western Piedmont crystalline subunit is lower than that in any of the limestone subunits. The rocks in this subunit are igneous and metamorphic, but many are not predominantly granitic like those in the rest of the Piedmont. Rocks of this type contain much less uranium, on average, than do limestones or granitic rocks (Faure, 1986).

Radon concentrations in ground water from subunits underlain by sandstone and shale are much more variable than those from subunits underlain by other rock types. Of these three subunits, one has a median radon concentration less than 300 pCi/L, one a median radon concentration between 300 pCi/L and 1,000 pCi/L, and one a median radon concentration greater than 1,000 pCi/L (fig. 3). The uranium content of sandstones and shales is commonly related to the uranium content of the sediments from which they formed. Radon concentrations in ground water from sandstones and shales can therefore be highly variable if these sediments were derived from different sources. Also, shales contain more uranium, on average, than do sandstones (Faure, 1986; Hem, 1985). Different relative amounts of sandstone and shale among these three subunits could therefore result in different median radon concentrations.

WHAT DOES ALL OF THIS INFORMATION ON RADON MEAN TO ME AS A HOMEOWNER?

Although radon concentrations in ground water of the Lower Susquehanna and Potomac River Basins are more likely to be higher in certain areas relative to others, the only way to be certain of the radon concentration in the water supplied by any given well is to have the water tested. Although differences in median radon concentration between subunits are apparent, there is a high degree of local variability within each subunit. This makes prediction of radon concentration at an individual well very difficult and imprecise. The USEPA and the Surgeon General of the United States recommend that all homes below the third floor be tested for airborne radon that may be entering the home through the basement (U.S. Environmental Protection Agency and Centers for Disease Control, 1992). In homes where high indoor radon levels are measured and where water is supplied by a privately owned well, the USEPA further recommends that the well water be tested as a potential contributing source of the airborne radon. For every 10,000 pCi/L of radon in water about 1 pCi/L of radon is released to the air, in addition to any airborne radon that may enter a home through the basement. If a large percentage of the radon in your house is from your water, the USEPA recommends that you consider installing a water treatment system to remove radon. Both homes and water supplies can be treated to reduce radon levels (U.S. Environmental Protection Agency, 1992).

WHERE CAN I GET MORE INFORMATION?

For more information about radon in water or radon in general, government contacts and additional reference materials are listed below. For the most current information on USEPA Maximum Contaminant Levels for radon in water contact the USEPA Safe Drinking Water Hotline, (800) 426-4791. Contacts for individual state agencies are included for information on current state regulations. Toll-free telephone numbers for state agencies can only be accessed from within that state. The data on which this report is based can be obtained by contacting the U.S. Geological Survey office in Towson, Md., or Lemoyne, Pa.

For additional information, contact:
District Chief
U.S. Geological Survey, WRD
840 Market Street
Lemoyne, Pennsylvania 17043-1586
(717) 730-6913

Contacts:

Safe Drinking Water Hotline - USEPA, Office of Water and Drinking Water, 4601 Resource Center, 401 M. Street S.W., Washington, D.C., 20460, (800) 426-4791

United States Environmental Protection Agency, Region 3, 841 Chestnut St. Philadelphia, Pa. 19107, (215) 597-9800

National Radon Hotline, Box 33435, Washington, D.C., 20035-0435, (800) SOS-RADON (800-767-7236)

Maryland Department of the Environment, 2500 Broening Highway, Baltimore, Md., 21224, (800) 872-3666

Pennsylvania Department of Environmental Protection, Bureau of Radiation Protection, Harrisburg, Pa., (800) 23R-ADON (800-237-2366) or (717)783-3594

Virginia Department of Health, 1500 East Main Street, Richmond, Va., 23219, (800) 468-0138

West Virginia Office of Environmental Health Services, 815 Quarrier Street, Suite 418, Charleston, W. Va., 25301, (800) 922-1255

Internet/World Wide Web Information:

USGS Radon Home Page:
http://sedwww.cr.usgs.gov:8080/radon/radonhome.html

USGS National Water-Quality Assessment (NAWQA) Program:
http://wwwrvares.er.usgs.gov/nawqa/nawqa_home.html

USEPA Radon Publications Page:
http://earth1.epa.gov/RadonPubs/

National Safety Council, Environmental Health Center; Radon and Indoor Air Quality:
http://www.cais.net/nsc/ehc/radon.html

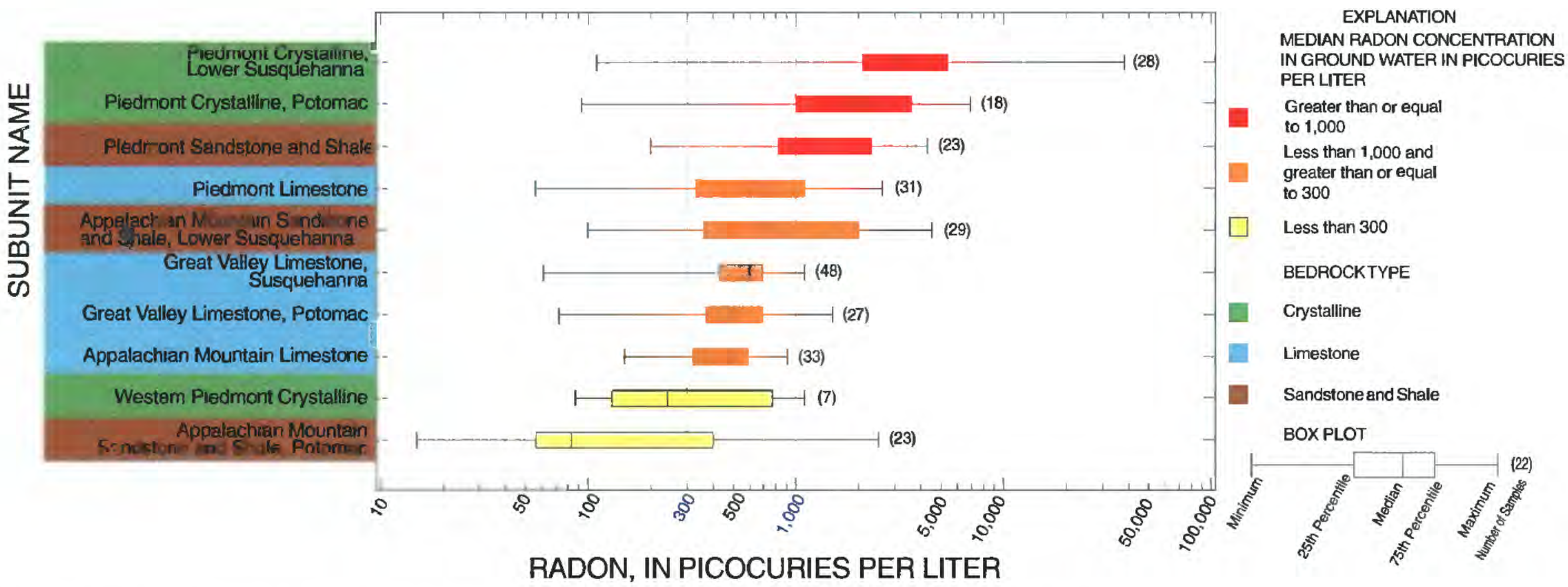

Figure 3. Distribution of concentrations of radon in ground water in the subunits sampled.

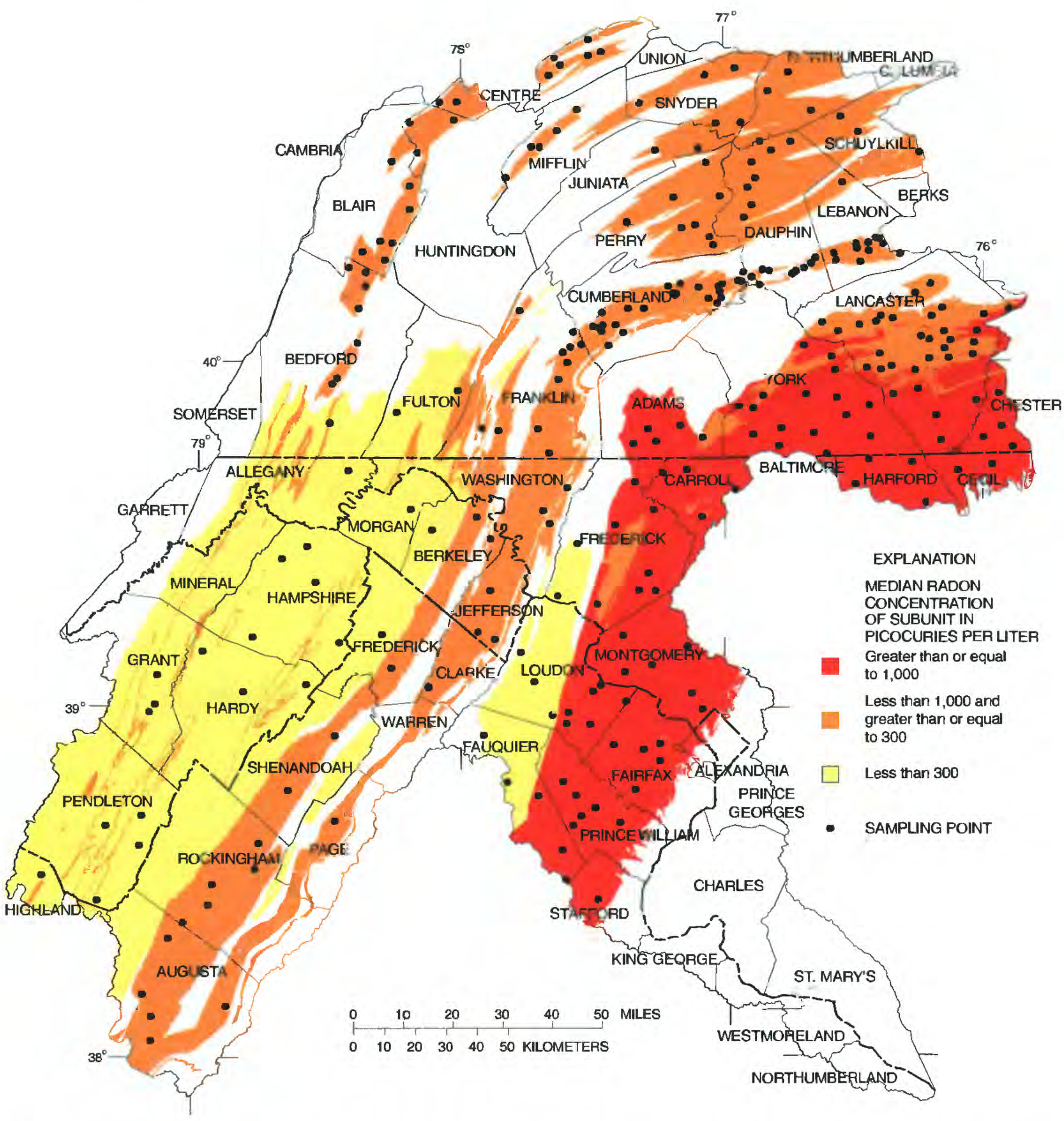

Figure 4. Sampling locations and subunits shaded to indicate median radon concentrations in ground water.

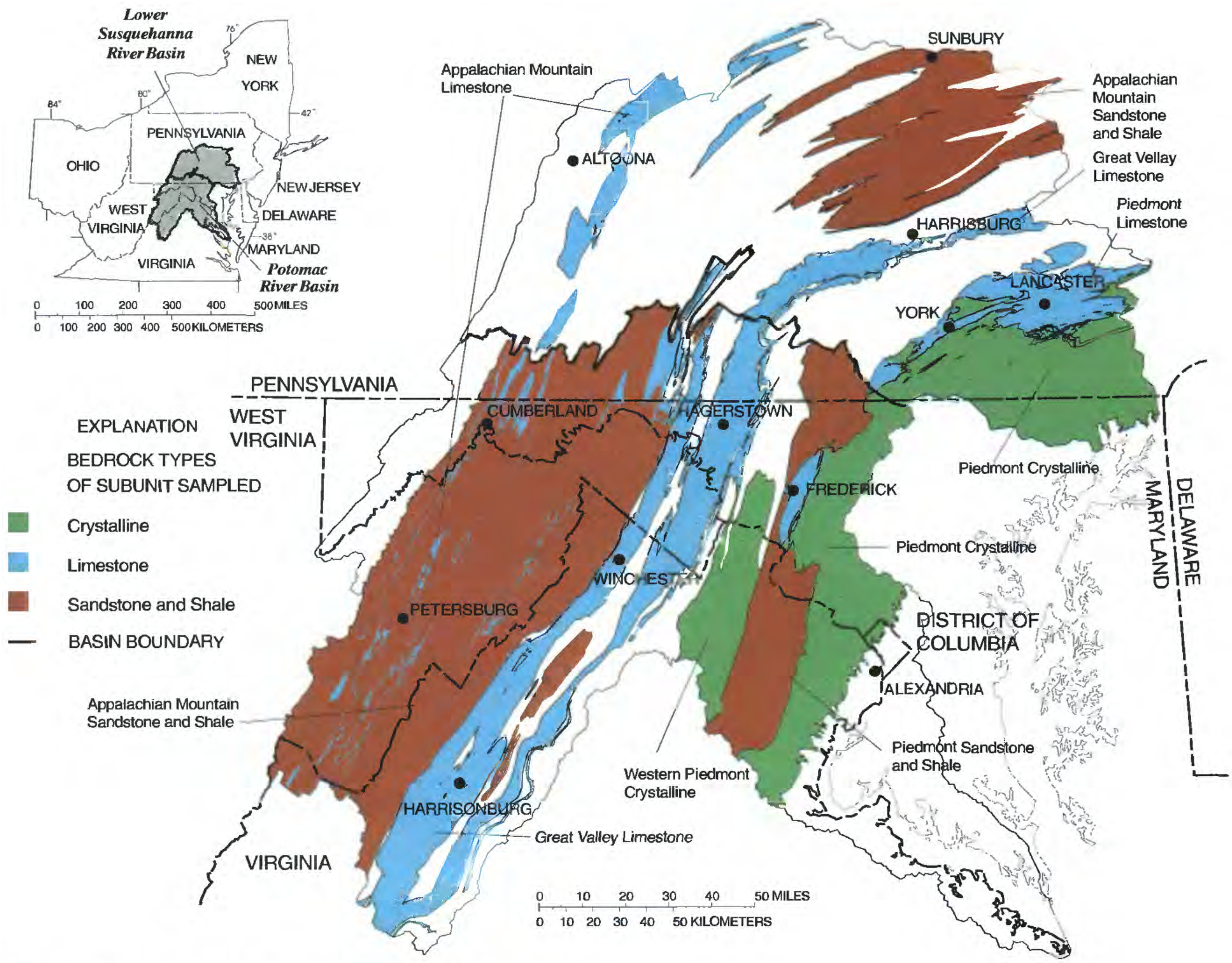

Figure 2. Location of subunits sampled and bedrock types.

of 300 pCi/L as a limit for the lowest grouping also may be significant because it is the proposed MCL for radon in drinking water.

Ground-water radon concentrations are highly variable, even within individual subunits. Concentrations of radon from 9 of the 10 subunits range from less than 300 pCi/L to greater than 1,000 pCi/L (fig. 3). The central tendency of radon concentrations in the subunit, represented by the median concentration, is useful to draw general conclusions about the occurrence of radon in ground water in that subunit but should not be used to predict concentrations at specific sites.

The subunits with median concentrations of radon greater than 1,000 pCi/L (shaded in red, figs. 3 and 4) are the Piedmont crystalline subunits (not including the Western Piedmont subunit) and the Piedmont sandstone and shale subunit. The highest median concentration of all the areas sampled (3,100 pCi/L) and the highest concentration from a single sample (38,000 pCi/L) are both in the Piedmont crystalline subunit of the Lower Susquehanna River Basin.

The group of subunits with median radon concentrations between 300 and 1,000 pCi/L (shaded in orange, figs. 3 and 4) includes all the subunits underlain by limestone bedrock and the Appalachian Mountain sandstone and shale subunit in the Lower Susquehanna River Basin. The limestone subunits generally have less variability in the range of radon concentrations, even though relatively large numbers of samples were collected in these subunits. The Appalachian Mountain limestone subunit has the least amount of variability of all the subunits and also is the only subunit that did not have any samples with radon concentrations greater than 1,000 pCi/L.

The subunits with median concentrations of less than 300 pCi/L (shaded in yellow, figs. 3 and 4) include the Western Piedmont crystalline subunit and the Appalachian Mountain sandstone and shale subunit in the Potomac River Basin. The sandstone and shale subunit has the lowest median concentration of all 10 subunits (about 80 pCi/L); however, the maximum concentration detected in the subunit was 2,500 pCi/L. This again shows a high degree of variability within these physiographic and bedrock type subunits.

Of the 267 ground-water samples collected, 80 percent contained radon concentrations above the proposed MCL (300 pCi/L), 31 percent were above 1,000 pCi/L, and less than 1 percent were above 10,000 pCi/L. These percentages are similar to results reported by Swistock and others (1993) for water from 989 wells throughout Pennsylvania.

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