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THE GEOLOGIC OCCURRENCE AND MIGRATION OF RADON GAS: A BRIEF REVIEW OF CURRENT INFORMATION AND MODELS RELEVANT TO MONROE AND LIVINGSTON COUNTIES

by

Richard Young, PhD.

SUMMARY

Radon, a naturally occurring radioactive gas, may enter homes from soils, soil gases, or groundwater and accumulate there. When inhaled in significant amounts, the radioactive decay products of radon may cause lung cancer.

In west-central New York (including southern Monroe and northern Livingston Counties), there are some thin, uranium-bearing shale beds that have elevated radioactivity levels and correspondingly high radon potential. Radon may migrate through permeable rocks, along faults, within groundwater, through pore spaces in unsaturated soils, and may enter cracked basement walls in areas where the surrounding soil is relatively permeable. This movement has been shown to be influenced by pressure gradients created by pumping water, groundwater movement (which is seasonally variable), atmospheric pressure changes, and building ventilation devices.

The difficulty of accurately predicting radon migration into buildings is caused by the variability of construction methods, geology, groundwater conditions, and pressure gradients. Nevertheless, professional interpretations using soils and geologic maps can identify potentially higher risk areas.

Structural factors, such as building materials, construction techniques, and ventilation devices, are not addressed in this geologically oriented review.

INTRODUCTION AND BACKGROUND

In nature, radioactive elements spontaneously decay or change into other elements or the same element with a different atomic mass (an isotope), with the accompanying release of radiation in the form of alpha particles (helium nuclei), beta particles (electrons), and gamma rays (similar to x-rays but more powerful).

Radon gas is produced by the natural radioactive decay series beginning with uranium-238 (238 indicates the mass of this isotope of uranium). During this complex sequence of events, radium-226 decays to radon-222, the isotope of concern, which has a half-life of 3.82 days. In other words, in 3.82 days, half of a given sample of radon-222 gas will decay into polonium-218, which in turn eventually produces polonium-214.

Radon gas in the air may enter the lungs directly or polonium isotopes may adhere to dust particles and enter the lungs. Further decays occurring in the lungs subject vulnerable tissues to alpha particles, the largest, slowest, and, in this case, the most damaging of the three types of radiation. The Environmental Protection Agency (EPA) has estimated that radon causes between 10,000 and 40,000 lung cancer deaths annually in the U.S. (1,2).

Because of the short half-life of radon, its presence in significant amounts indicates either that the source must be relatively close to the sampling point (in soils, soil gases, or groundwater) or that there is a relatively direct and open pathway from a more distant source deeper within the ground. It is believed that natural or induced pressure gradients may be as important as either the source or structural pathways in explaining why radon gas may accumulate preferentially in a given building.

RADON IN NATURAL ROCK FORMATIONS, OVERBURDEN, AND GROUNDWATER

Although primary uranium is commonly associated with igneous and metamorphic rocks, uranium compounds occur in sedimentary rocks, where they have been concentrated by geochemical processes either during formation of the original sediment or, later, by the action of groundwater. In the sedimentary rock sequence in west-central New York, key horizons (distinct layers) containing radioactivity are commonly logged in oil and gas wells. These layers are relatively thin and most are shale beds. However, recent evidence from Onondaga County has shown that where fractured or permeable carbonate and/or evaporite rocks underlie uranium-bearing shale beds, radioactivity levels may be much higher than expected in the rocks adjacent to the shales. It is assumed that groundwater has redistributed the uranium from the shale downward through fractures into the more permeable carbonate rocks over tens of millions of years. Carbonates (rocks such as limestone, dolostone, and marble) are usually among the least radioactive of all rocks. However, where radioactive elements have been introduced into carbonates, radon may be more easily released from such fractured carbonate rocks than from the adjacent shale source rock. Due to this juxtaposition of the uranium-bearing shale with a more permeable formation, radon emission might be greater than otherwise predicted from bedrock composition (see following section on radon migration and accumulation) (3).

Two of the more conspicuous radioactivity zones encountered in local rocks are: 1) a shale bed in the Geneseo Shale immediately above the Tully limestone or Leicester Pyrite (Fig. 1, A), and 2) within the lower Marcellus Formation (mainly shale) which is the formation directly south of the Onondaga limestone escarpment (Fig. 1, B). The Marcellus-Onondaga-Syracuse Formation interval in Monroe County appears to have produced a redistribution of uranium sources analogous to the geologic conditions documented for the same stratigraphic interval near Syracuse (3). Test results from the New York State Department of Health show elevated radon values ranging between means of 10.5 and 19.3 pCi/liter for the Towns of Scottsville, Mendon, Rush, and Wheatland, based on a minimum of 10 houses in each area. The current EPA safe maximum level is 4 pCi/liter.

The rock formations of concern are found in a somewhat irregular east-west belt through southern Monroe and northern Livingston Counties (Fig. 2). The irregular shape of the belt is due to glacial erosion of the buried rock layers. The resulting sinuous rock outcrop patterns are obscured by glacial till, sand, and gravel deposited by the receding glacier and by soils created by the weathering and erosion of these glacial overburden deposits.

Other shale beds with measurable radioactivity values exist, but the Tully and Marcellus horizons are the most uranium-enriched in or near Monroe County, and they have the highest reported uranium values. If radon production is not found to be associated with these two layers and adjacent permeable carbonate or evaporite rocks, it is unlikely to be a significant problem elsewhere, assuming no other undetected sources of shallow radioactivity exist.

It is possible, but not confirmed, that limited amounts of radon could migrate upwards from the crystalline basement rocks, deeply buried below the sedimentary rocks, through somewhat more permeable fault zones (fractures in the bedrock). Most of the known fault zones in the region are obscured by the glacial overburden, but many others probably are hidden beneath the glacial deposits.

RADON MIGRATION AND ACCUMULATION

Because radon is a gas, it may move more readily than the solid by-products of the radioactive decay series into and through the groundwater that saturates fractured rocks

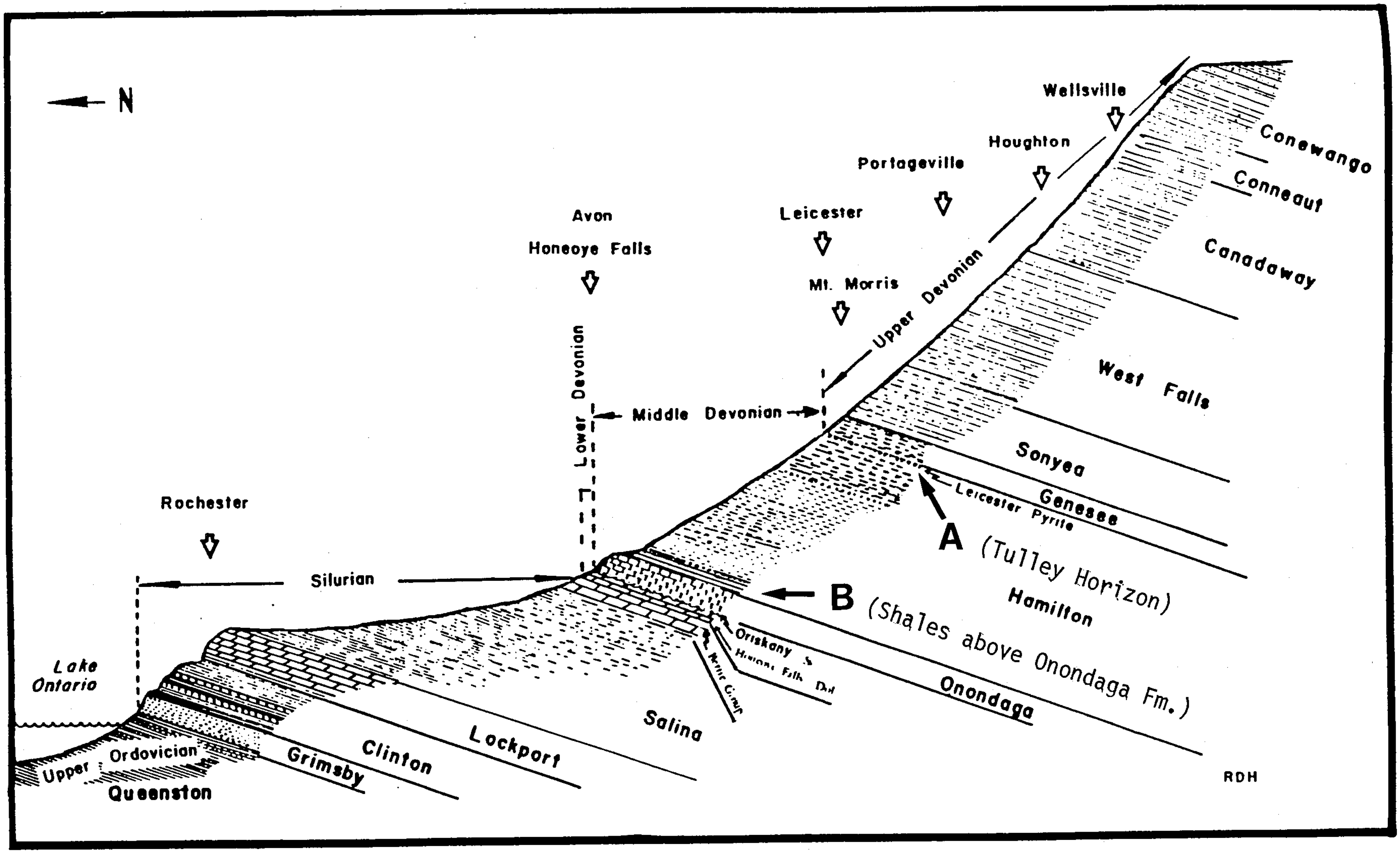

FIGURE 1. Genesee Valley Stratigraphic Sequence with Radioactivity Zones A, B.
Modified from Rochester Academy of Science Bulletin v. 15, no. 2, p. 113

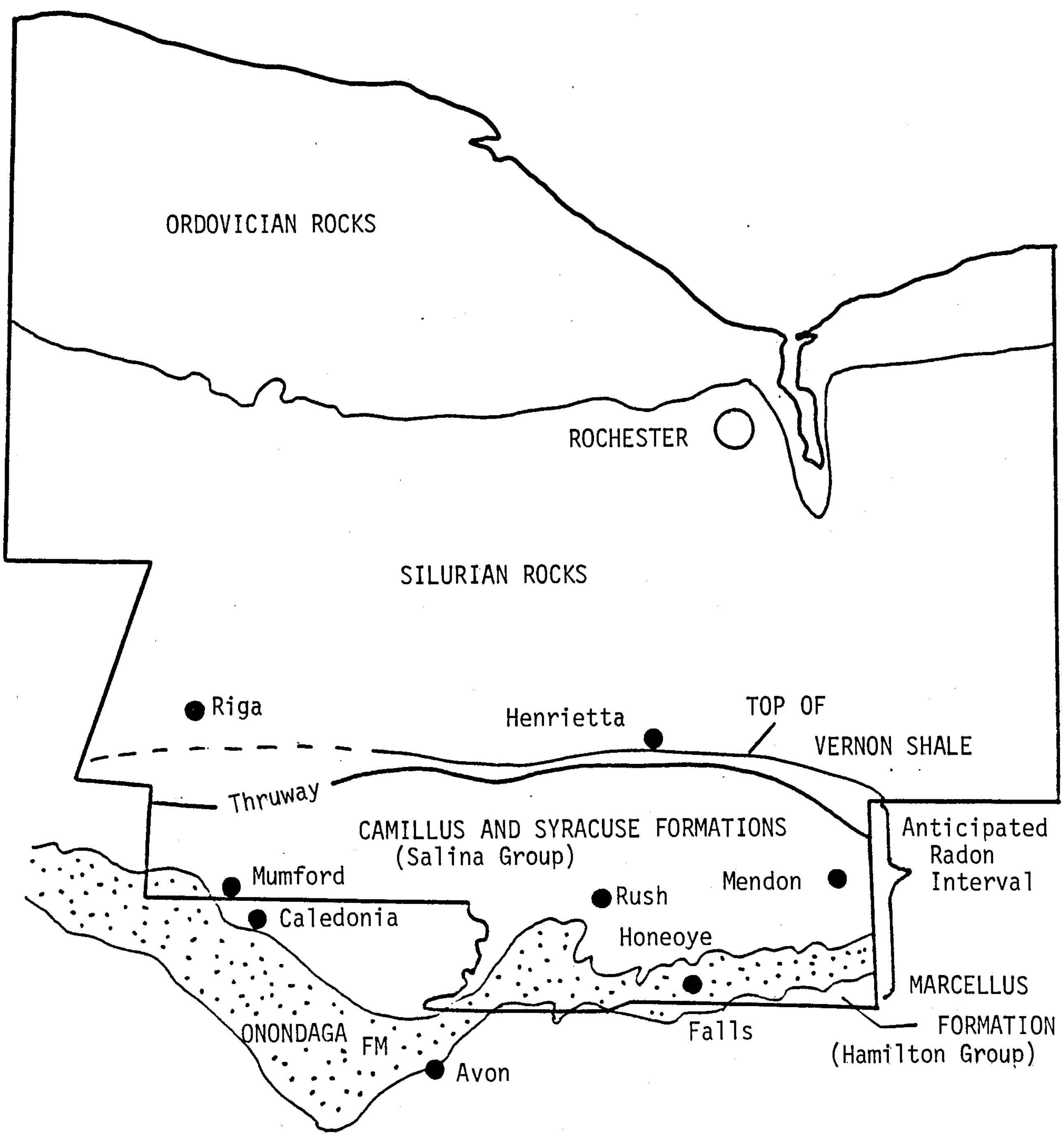

Figure 2. General area of enhanced radon levels (anticipated) between base of Marcellus Fm. and top of Vernon Shale. Radioactivity is leached from Marcellus shale down through fractured carbonate and evaporite units below. Based on analogy with Onondaga County (see Hand and Banikowski, 1988)

or permeable soils. Radon also moves directly through the pore spaces (air spaces) of unsaturated soils. Because of the short half-life of radon, its presence indicates continuous migration from a relatively nearby source region in a period of days or weeks.

It has been proposed (4) that pressure gradients produced by pumping water wells, atmospheric changes, descending or ascending groundwater, and building ventilation devices can significantly influence the movement of radon towards regions of lower pressure (similar to the action of a vacuum pump). For example, radon could be pulled toward the depressed water table surface near a pumped well. When the pump is turned off, the resulting rise of the water level could force the gas upward ahead of the water surface. It has also been suggested that the higher clay content of some surface soils (which makes them relatively impermeable) could enhance the lateral movement of radon into more permeable basement structures that protrude into a deeper, more permeable zone below. Thus, clay-rich soils at the surface may hide or exacerbate problems at greater depths. It has been suggested that buildings whose foundations have been cut into slopes may be more susceptible to radon accumulation than those on flatter ground (4).

In the Monroe County area the upward migration of radon from bedrock could be expected to correlate closely with areas where permeable sandy soils overlie rocks with higher radioactivity concentrations. Random joint patterns and secondary solution pathways in bedrock could complicate or influence the pattern of radon migration into and through the overlying soils. Because of the nonhomogeneous character of the glacial overburden and its poorly mapped subsurface variations, it is difficult to propose a simple model for regions of enhanced radon movement toward structures. In addition, considering all of the geologic variables involved (soil textures, rock fractures, groundwater conditions, and pressure gradients), it is apparent that the potential migration of radon into a building or home can be highly variable within a specific region.

Preliminary reports on the occurrence of radon suggest an emerging pattern similar to that shown for Onondaga County in the interval between the Marcellus and Vernon Formations (Fig. 1).

It has recently been shown that radon values show seasonal variations, with higher values in New York occurring in late summer-early fall and lower values in late winter-early spring. The explanation for this variation is not well understood and not all areas of the country show similar seasonal variations (5).

SAMPLING SUGGESTIONS AND CONCLUSIONS

It would be logical to concentrate future sampling in areas where the soils maps indicate sandy soils over suspected bedrock formations, especially near the top of the Tully interval or above and below the Marcellus Formation. This should include locations above buried bedrock valleys that might have been eroded down into such bedrock formations and may be filled with sandy aquifers of unknown extent. Areas of southern Monroe and northern Livingston Counties (Fig. 1) between the Marcellus and Vernon Formations fit this profile by analogy with the radon distribution in Onondaga County (3).

In order to delineate prime target areas, more direct sampling of the soils and groundwater in selected locations could be accomplished by water well sampling. It also might be appropriate to select a few sampling sites where actively pumped water wells in sandy overburden are located relatively near basements, in order to test the possible effects of groundwater pumping on radon migration.

The radon enhancement models that assume water level changes create pressure influences on radon migration also suggest potential seasonal variations in contamination levels (4). Rising water levels in the spring of the year may lead to differences in radon values as compared to later in the summer. However, if the radon is moving toward the surface at a relatively constant rate, any such variations due to seasonal groundwater recharge effects should represent short-term variations. Nevertheless, government agencies or homeowners doing short-term radon sampling should be aware of the potential for seasonal variations, which differ throughout the U.S., depending on climatic factors.

Recent radon studies indicate that many of the potential variables affecting radon migration and accumulation are not well understood. The information that has emerged suggests that radon accumulation and movement can be very localized and time variable. It also can be significantly influenced by the placement of a structure relative to the water table and the topography of a site. Other obvious structural factors (such as building materials and ventilation) are not the subject of this discussion.

An appropriate sampling plan should be designed with the use of soils maps, geologic maps, and professional advice to assure that the areas with the highest potentials are adequately sampled and that all reasonably anticipated variables have been considered in the sample plan.

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