THE RADON-HAZARD-POTENTIAL MAP OF UTAH

by

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Utah Geological Survey

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ABSTRACT

Radon (^{222}Rn) is a naturally occurring radioactive gas formed by the decay of uranium (^{238}U) which can be found in small concentrations in nearly all geologic materials. When radon is inhaled, its decay products are a significant cause of lung cancer. Radon gas has long been recognized as an occupational health hazard to workers in uranium mines, however the hazard from accumulation of radon gas at lower concentrations in buildings has only recently been recognized. The indoor-radon hazard depends on a variety of geologic and non-geologic factors.

Although the influence of non-geologic factors such as building construction type and weather is difficult to measure, geologic factors that influence indoor-radon hazards can be quantified. A numerical rating system based on geologic factors (uranium concentration, soil permeability, and ground-water depth) was developed to assess and map the relative radon-hazard potential for the state.

Areas underlain by uranium-enriched rock or soil are generally associated with a high radon-hazard potential. Uranium-enriched geologic materials typically include granitic rocks, metamorphic rocks, volcanic rocks, organic-rich shales, marine sandstones, and soil derived from uranium-enriched rocks. Locations of high surface concentrations of uranium are shown on the map. Rock units with the highest surface uranium concentrations are the Permian Cutler Group and Phosphoria Formation, the Triassic Moenkopi and Chinle Formations, the Jurassic Morrison Formation, the Cretaceous Dakota Sandstone and Mesaverde Group, the Tertiary Uinta Formation, and Tertiary volcanic rocks.

Geologic factors that impede radon movement in soil gas, such as impermeable soil or shallow ground water, reduce the radon hazard and are generally associated with a low radon-hazard potential. Impermeable soils are typically associated with clay-rich layers. Water saturation of a rock or soil can also inhibit soil gas migration as radon is trapped in and moves with the ground water.

The Basin and Range - Colorado Plateau transition zone generally has the highest hazard potential in Utah, primarily due to uranium-enriched Tertiary volcanic rocks. The Colorado Plateau and Middle Rocky Mountains provinces have moderate to high hazard potential. Although soil and ground-water conditions are generally favorable for indoor-radon hazards in these provinces, low uranium levels restrict the hazard potential. The Basin and Range Province has the lowest hazard potential. Clay-rich soils and shallow ground water are common in the broad basins that typify this province. In the Basin and Range, a high hazard potential may be found in mountain ranges where geologic factors are favorable.

INTRODUCTION

Radon is an odorless, tasteless, radioactive gas of geologic origin that is an environmental concern because of its link to lung cancer. Unlike most geologic hazards which are natural, dynamic, earth processes that adversely affect both life and property, radon is a hazard only to living things. Radon has been found in many buildings throughout the United States in sufficient concentrations to pose a health hazard to building occupants.

Radon forms as a product of radioactive decay. The most abundant radon isotope, ^{222}Rn, forms as a product of the decay of uranium (^{238}U). Other radon isotopes form by decay of thorium (^{232}Th) and one other uranium isotope (^{235}U). However ^{222}Rn, with a half-life of 3.825 days, is the most significant contributor to indoor radon. All subsequent references to radon and uranium refer to ^{222}Rn and ^{238}U.

Most radon atoms are exhaled before they can decay and emit dangerous radiation to the lungs. However, the radioactive isotopes from radon decay (radon decay progeny) are easily adsorbed by lung tissue. Health officials believe that breathing elevated levels of radon over time increases a person's risk of lung cancer (Jacobi and Eisfeld, 1982; National Council on Radiation Protection and Measurements, 1984a, 1984b; Samet, 1989). Inhalation of radon and radon decay progeny was recognized as a health problem in the 1950s and early 1960s, when studies on workers in underground uranium mines concluded that high concentrations of radon found in the mines contributed to an increased lung cancer rate among miners (National Council on Radiation Protection and Measurements, 1984b).

Geology influences the local concentration, emanation, and migration of radon. Because radon is an inert gas that is highly mobile, it can move with the air or be dissolved in water without chemical alteration, and can migrate through cracks or voids in rock or soil (Tanner, 1980). Normally, radon gas dissipates harmlessly into the atmosphere. However, high indoor concentrations of radon may occur where favorable geologic conditions exist.

Lower concentrations of uranium in rock and soil were not believed to contribute to indoor radon until associations between elevated indoor-radon levels and lower uranium concentrations in rock were discovered (Smith and others, 1987). The potential for elevated levels of indoor radon can now be associated with rock having average uranium concentrations as low as 15 parts per million (ppm) or less (Durrance, 1986). The U.S. Environmental Protection Agency (EPA) estimates that as many as 40,000 Americans will die each year from lung cancer caused by long-term inhalation of radon gas (Schmidt and others, 1990). Many areas of Utah are underlain by rock which may produce hazardous indoor-radon levels (Sprinkel, 1987; Sprinkel and Solomon, 1990; Solomon, 1992b).

With funding from the State Indoor Radon Grant (SIRG) Program, administered by the U.S. Environmental Protection Agency (EPA), the Utah Geological Survey (UGS) and Utah Division of Radiation Control (UDRC) are investigating the relationship between geology and indoor-radon hazards. A preliminary geologic assessment by the UGS (Sprinkel, 1987) indicated areas in the state which could be generalized sources of radon. In 1987, the UDRC conducted a survey of indoor-radon levels in these source areas (Sprinkel and Solomon, 1990). Based on the survey results, the UGS conducted detailed field investigations of radon-hazard potential in east Sandy, east Provo, the St. George basin, and Ogden Valley (Solomon and others, 1991; Solomon, 1992a; Solomon, in preparation). The Radon-Hazard-Potential Map of Utah is an update of Sprinkel (1987), and incorporates a new hazard-classification scheme similar to that used in the detailed field investigations. Future studies will continue to define the relationship between geology and indoor-radon hazards through detailed field investigations of local areas.

The purpose of this map is to provide researchers, government officials, consultants, developers, and concerned citizens with a guide to radon-hazard potential in Utah. It can be used to indicate areas where detailed indoor-radon surveys and geologic studies are necessary to determine the need for radon-resistant construction. However, because of the small scale of the map and the complex relationships between geologic and non-geologic factors that control indoor-radon levels, this map should not be substituted for detailed site investigations or used as a predictor of actual indoor-radon levels.

FACTORS CONTRIBUTING TO INDOOR-RADON HAZARDS

People are particularly subject to radon gas in buildings or enclosures with poor air circulation. Radon migrates into buildings through cracks in the basement or through other foundation openings such as those for utility pipes (Lafavore, 1987). High concentrations of radon most often occur in basements or low crawl spaces (Fleischer and others, 1982) where the building is in contact with the ground. Radon never achieves dangerous levels outdoors because movement of the air dissipates it.

The concentration of radon in a building depends on a complex relationship between geologic and non-geologic factors. Four principal factors contribute to elevated indoor-radon concentrations: (1) elevated uranium levels in the soil or rock on which a structure is built, (2) soil and ground-water conditions that do not restrict the movement of radon, (3) porous building materials or foundation openings below grade, and (4) lower atmospheric pressure inside a building than outside (Tanner, 1986). Factors (1) and (2) are geologic factors that can be measured and characterized regionally; the magnitude of their effects can vary locally but generally remains constant. Factors (3) and (4) are non-geologic factors that are difficult to measure and cannot be characterized regionally; the magnitude of their effects is variable and fluctuates with the weather, type of construction, and lifestyle of the occupants. Thus, although the same radon-hazard potential from geologic factors may exist, indoor-radon levels can still vary from building to building.

RADON-HAZARD POTENTIAL

Geologic Considerations

Geologic considerations affecting radon-hazard potential include the distribution of uranium-enriched rocks and factors that may enhance or impede radon movement. Muessig (1988) shows a correlation between areas with mean equivalent uranium (eU) concentrations greater than 2.4 ppm and indoor-radon concentrations exceeding 4 picocuries per liter (pCi/L) (148 Becquerels per cubic meter [Bq/m^3]), the remedial action level recommended by the Environmental Protection Agency (1986). Once uranium is present in sufficient concentrations, the radon it generates must be able to migrate to the surface. Although radon easily dissolves into water, which provides an effective medium for it to migrate from a source, water saturation of rock and soil inhibits radon migration into overlying buildings by reducing diffusion and blocking the flow of soil gas (Tanner, 1980). The permeability of rock or soil also influences the ability of radon to migrate to the surface. Impermeable soils block the flow of soil gas, whereas permeable soils provide pathways for radon migration (Tanner, 1980; McLemore and others, 1991).

Other geologic factors such as hydrothermal processes, expansive soil, and active faults, which could not be considered due to the scale of the map, may also contribute to locally high indoor-radon levels. Anomalous radon concentrations have been measured in Utah where there is active hydrothermal or ground-water upwelling along faults (Nielsen, 1978). Numerous areas of water upwelling along faults are present in Utah (Mundorff, 1970). Expansive soil shrinks or swells with changes in moisture content. The repeated expansion and contraction of the soil can damage building foundations (thereby enhancing radon entry into the structure). Expansive soils typically develop cracks when dry, providing additional pathways of soil-gas transport (Peake and Schumann, 1991). Active faults may produce significant radon anomalies by increasing permeability and thereby enhancing near-surface radon concentrations (Tanner, 1980; Sprinkel and Solomon, 1990).

Hazard-Potential Ratings

Previous studies (Gundersen and others, 1988; Solomon and others, 1991; Solomon, 1992a) have developed hazard-classification schemes designed to accommodate geologic factors that influence indoor-radon levels in specific geologic settings. The classification scheme of Solomon (1992a) is applicable to a wide range of settings, and a similar scheme is used here. This classification scheme uses three factors to evaluate radon-hazard potential: (1) uranium concentration, (2) soil permeability, and (3) ground-water depth. Numerical ratings from 1 to 3 were assigned to each factor, with higher ratings corresponding to conditions favorable for elevated indoor-radon concentrations (table 1). Basic-data maps developed for each of the three geologic factors used units corresponding to ratings shown in table 1. The Radon-Hazard-Potential Map was derived by overlaying the three basic-data maps, summing hazard ratings, and tracing contacts based on summed ratings for all three geologic factors. Each factor is weighted equally because there is insufficient evidence of the relative contribution of individual factors to the radon hazard. Three radon-hazard-potential categories were established based on the cumulative totals of the three factors (table 2).

The radon-hazard-potential categories shown on the map are: (1) high, areas with geologic factors that are generally favorable for elevated indoor-radon concentrations; (2) moderate, areas with factors that are favorable for elevated indoor-radon concentrations, but which are limited by one or more unfavorable factors; and (3) low, areas with geologic factors that are generally unfavorable for elevated indoor-radon concentrations. The distribution of radon-hazard-potential categories shown on the map are in general agreement with detailed investigations conducted by the UGS in the east Sandy, east Provo, St. George basin, and Ogden Valley areas (Solomon and others, 1991; Solomon, 1992a; Solomon, in preparation).

Uranium Concentration

Airborne radiometric surveys measure ground-surface gamma-ray intensity. Uranium concentrations determined from such surveys have been used as a factor in evaluating radon-hazard potential (Flood and others, 1990; Peake and Schumann, 1991). Data from airborne surveys were used to evaluate radon-hazard potential in Utah. Uranium concentration in Utah is shown on a 1:1,000,000 scale computer-generated uranium contour map derived from the national map of Duval and others (1989), and was compiled from National Uranium Resource Evaluation (NURE) airborne radiometric surveys (Aero Service, 1979; EG&G Geometrics, 1979a, 1979b; Geodata International, 1979a-f, 1980, 1981). Equivalent uranium (eU) is measured by bismuth (^{214}Bi), a daughter product of ^{222}Rn in the ^{238}U decay series, which is approximately proportional to near-surface radon concentrations (Flood and others, 1990; Duval, 1991). Uranium concentration was grouped into three categories with eU concentrations of: (1) less than 1.5 ppm; (2) 1.5 ppm or greater, but less than 2.5 ppm; and (3) 2.5 ppm or greater (table 1).

Soil Permeability

Soils in Utah have been mapped and classified by the U.S. Soil Conservation Service (SCS) into 67 generalized soil associations and 4 miscellaneous land types (Wilson and others, 1973). The SCS soil surveys provide data on soil permeability. Based on SCS permeability data, Utah soils were grouped into categories of soils with hydraulic conductivities of: (1) less than 0.6 inches/hour (4.2×10^{-4} cm/sec); (2) 0.6 inches/hour (4.2×10^{-4} cm/sec) or greater, but less than 6.0 inches/hour (4.2×10^{-3} cm/sec); and (3) 6.0 inches/hour (4.2×10^{-3} cm/sec) or greater (table 1). Soil permeabilities greater than 6.0 inches/hour (4.2×10^{-3} cm/sec) may increase the potential for indoor radon even in areas with low to moderate eU concentrations (Peake and Schumann, 1991).

Miscellaneous land types include rock land (sandstone bedrock with or without a thin cover of residual soil common in southern Utah), badland (shale and sandstone outcrops with shallow and very shallow soils common in eastern Utah), rock land of the high mountains (steep colluvial areas and bedrock with shallow, stony soils common in the Wasatch Range and Uinta Mountains), and playas (salt flat remnants of intermittent shallow lakes common in western Utah) (Wilson and others,

Table 1. *Hazard-potential rating of geologic factors.*

FACTOR	RATING		
	1	2	3
eU CONCENTRATION (ppm)	Less than 1.5	1.5 or greater, but less than 2.5	2.5 or greater
PERMEABILITY (in/hr)	Less than 0.6	0.6 or greater, but less than 6.0	6.0 or greater
GROUND-WATER DEPTH (ft)	Generally less than 10	Generally less than 30	Greater than 30

Table 2. *Radon-hazard-potential categories. See table 1 for rating value of each factor.*

RADON-HAZARD POTENTIAL	RATING TOTAL
Low	3-5
Moderate	6-7
High	8-9

1973). Playas, which contain clay-rich impermeable soils, were included in the low permeability category (table 1). Other land types, which have shallow, highly permeable soils or bedrock exposed at the surface, were included in the high permeability category (table 1).

Ground-Water Depth

Ground-water depths were taken from a map by Hecker and others (1988), which groups shallow ground water into three categories where the depth to ground water is: (1) generally less than 10 feet (3 m); (2) generally less than 30 feet (9 m), including areas where the depth is less than 10 feet (3 m) that are too small or where data were insufficient to delineate separately; and (3) generally greater than 30 feet (9 m) (table 1). Local perched ground-water conditions and seasonal ground-water fluctuations were not considered in ground-water depth.

Map Limitations

Because of the small scale of the map (1:1,000,000) and the complex relationships that exist between geologic and non-geologic factors controlling radon levels, this map should not be used to predict actual indoor-radon levels. The scale of the map precludes identification of small areas of higher or lower radon-hazard potential contained within the hazard-potential areas depicted on the map. Radon-hazard potential is relative, and all map boundaries between radon-hazard potential categories are approximate and gradational.

ASSAY DATA AND ROCK SOURCES OF URANIUM AND URANIUM-ENRICHED SEDIMENT

Utah has significant economic deposits of uranium. Included on the map are locations of outcrop and mine talus assays which indicate surface concentrations of uranium. Assay data were compiled from uranium surveys (table 3) and NURE 1°x 2° quadrangle evaluation reports (table 4), and entered into a computerized database showing location, type of assay, concentration, and geologic formation. The assay data come primarily from uranium-enriched units and known economic deposits of uranium. Although data from nearly 2,600 total assays were compiled, only assays with a uranium concentration of 20 ppm or greater are shown on the table and map. Assay locations are keyed to the reference from which the data were compiled (tables 3 and 4).

Although airborne radiometric measurements were used to assess uranium concentrations when preparing the map, ground-based survey information is presented because it helps identify rock units with high concentrations of uranium that may act as local sources of uranium-enriched sediment. Identifying potential uranium sources is important for evaluating radon-hazard potential in detailed investigations and in geologic-hazards mapping. Tables 5 and 6 list assay data and occurrences of uranium

Table 3. *Selected uranium surveys in Utah.*

ASSAY LOCATIONS	REFERENCE
1	Corey, 1959.
2	Beroni and others, 1953.
3	Gott and Erickson, 1952.
4	Wyant, 1953.
5	Stugard, 1951.
6	Wyant, 1951.
7	Granger and Beroni, 1950.
8	Granger and Bauer, 1950.
9	Larson, 1957.
10	Bush and Lane, 1981.
11	Brooke and others, 1951.
12	Blair, 1954.
13	Beroni and others, 1952.
14	Beroni and McKeown, 1952.
15	Bauer and Staatz, 1951.
16	Annes, 1956.
17	Rocky Mountain Geochemical, unpublished data.
18	Black, 1980.

Table 4. *NURE 1°x 2° quadrangle evaluation reports in Utah.*

ASSAY LOCATIONS (PLATE 1)	1°x 2° QUADRANGLE	REFERENCE
19	Escalante	Peterson and others, 1982.
20	Cortez	Campbell and others, 1982a.
21	Vernal	Craig and others, 1982.
22	Price	Campbell and others, 1982.
23	Delta	Cadigan and Ketner, 1982.
24	Salina	Lupe and others, 1982.
25	Richfield	Bromfield and others, 1982.
26	Moab	Campbell and others, 1982b.
27	Ogden	Madson and Reinhart, 1982.

Table 5. Outcrop and mine talus assay data for geologic units in Utah[1].

AGE	GEOLOGIC UNIT	NUMBER OF ASSAYS	CONCENTRATION[2] MEAN	MAXIMUM
Tertiary	Sevier River Formation	8	18.0	113
	Tertiary volcanic rocks (Mount Belknap Volcanics; Osiris Tuff; Mount Dutton Formation; Bullion Canyon Volcanics; Tunnel Spring Tuff; Isom Formation; Needles Range Group; other pyroclastic flows, tuffs, and rhyolite flows)	557	20.5	11532
	Crazy Hollow Formation	6	21.3	741
	Uinta Formation	10	63.9	12500
	Green River Formation	3	13.9	77.3
	Wasatch Formation	2	23.7	51
	Colton Formation	5	20.9	344
	Flagstaff Limestone	2	2.4	3.1
Cretaccous	Mesaverde Group	50	72.1	1696
	Straight Cliffs Formation	2	206.6	508
	Dakota Sandstone	51	151.4	9700
	Cedar Mountain Formation	3	2.8	7.8
Jurassic	Morrison Formation	462	3.5	21030
	Summerville Formation	7	7.8	359
	San Rafael Group	6	1.0	1.8
	Kayenta Formation	3	0.7	1.4
Triassic	Chinle Formation	233	124.9	477847
	Moenkopi Formation	18	13.0	1780
Permian	Park City Formation	6	25.0	110
	Plympton Formation	2	14.2	17.4
	Kaibab Limestone	7	20.0	184
	Phosphoria Formation	44	91.1	305
	Cutler Group	42	19.2	146110
Permian/ Pennsylvanian	Rico Formation	2	44.8	45.1
Pennsylvanian	Callville Limestone	2	10.2	16.1
Mississippian	Chainman Shale	10	7.0	39.5
	Deseret Limestone	10	35.7	68.9
	Woodman Formation	10	22.5	74.1
Devonian	Pilot Shale	2	10.0	10.7
Ordovician	Pogonip Group	2	0.5	1.5
Cambrian	Pioche Formation	2	6.0	7.9
	Tintic Quartzite	2	0.5	0.6
	Quartzite of Clarks Basin	15	1.2	4.9
Precambrian	Schist of Stevens Spring	15	3.3	6.7
	Elba Quartzite	57	1.5	15
	Quartzite of Yost	18	1.1	7.1
	Schist of Upper Narrows	9	1.9	5.9
	Red Creek Quartzite	13	128.4	4833
	Archeozoic adamellite intrusions and Green Creek Complex	40	3.2	27
	Farmington Canyon Complex	4	6.0	28

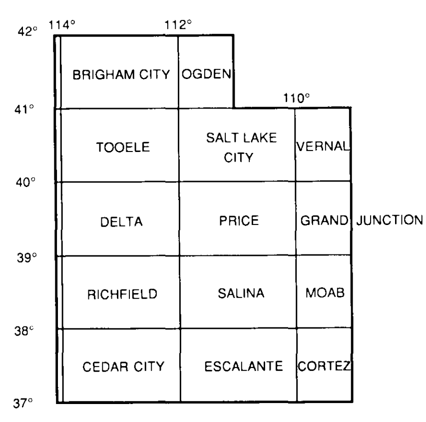
[1] Based on data compiled in the Utah Geological Survey uranium assay database from uranium surveys and NURE quadrangle evaluation reports (see tables 3 and 4).

[2] In parts-per-million (ppm) uranium. Mean is geometric mean concentration of all assays; maximum is highest reported assay concentration.

***Table 6.** Occurrences of uranium in mines and prospects for geologic units in Utah[1].*

AGE	GEOLOGIC UNIT	1° x 2° QUADRANGLE CORTEZ	ESCALANTE	RICHFIELD	PRICE	VERNAL	OGDEN	SALINA	MOAB	DELTA
Tertiary	Sevier River Formation	-	-	1	-	-	-	-	-	-
	Tertiary volcanic rocks	-	1	118	-	-	-	1	1	33
	Crazy Hollow Formation	-	-	3	1	-	-	-	-	-
	Goldens Ranch Formation	-	-	-	1	-	-	-	-	-
	Uinta Formation	-	-	-	-	24	-	-	-	-
	Green River Formation	-	-	-	6	-	-	-	-	-
	Wasatch Formation	-	-	-	-	-	6	-	-	-
	Colton Formation	-	-	-	3	-	-	-	-	-
Tertiary/ Cretaceous	North Horn Formation	-	-	-	2	-	-	-	-	-
Cretaceous	Mesaverde Group	-	-	-	2	10	-	-	-	-
	Mancos Shale	-	-	-	-	-	-	-	1	-
	Burro Canyon Formation	-	-	-	-	-	-	-	2	-
	Dakota Sandstone	-	3	-	-	-	-	-	2	-
Jurassic	Morrison Formation	142	47	-	10	2	-	63	239	-
	Summerville Formation	-	-	-	-	-	-	-	1	-
	San Rafael Group	-	-	-	-	-	-	3	-	-
	Navajo Sandstone	-	-	-	-	-	-	-	1	-
	Kayenta Formation	-	-	-	-	-	-	-	1	-
Triassic	Chinle Formation	41	146	-	6	-	-	145	101	-
	Moenkopi Formation	-	13	-	1	-	-	4	-	-
Permian	Park City Formation	-	-	-	-	4	2	-	-	-
	Plympton Formation	-	-	-	-	-	-	-	-	1
	Kaibab Limestone	-	-	-	-	-	-	1	-	-
	Phosphoria Formation	-	-	-	-	-	8	-	-	-
	Cutler Group	-	-	-	-	-	-	1	28	-
Permian/ Pennsylvanian	Rico Formation	-	-	-	-	-	-	-	1	-
Pennsylvanian	Hermosa Group	-	-	-	-	-	-	-	1	-
Mississippian	Chainman Shale	-	-	-	-	-	-	-	-	1
	Deseret Limestone	-	-	-	-	-	-	-	-	2
	Woodman Formation	-	-	-	-	-	-	-	-	1
	Brazer Dolomite	-	-	-	-	-	1	-	-	-
Ordovician	Pogonip Group	-	-	1	-	-	-	-	-	-
	Fillmore Formation	-	-	1	-	-	-	-	-	-
Precambrian	Red Creek Quartzite	-	-	-	-	1	-	-	-	-
	Farmington Canyon Complex	-	-	-	-	-	11	-	-	-

[1] Compiled from NURE quadrangle evaluation reports (see table 4).



(defined as deposits exceeding minimum size and grade criteria specified by the U.S. Department of Energy *in* Mickle, 1978) for geologic units in Utah. Assay data are listed by geologic unit, number of assays, and mean and maximum uranium concentration (table 5). Mean concentration was determined by taking the root of the product of the concentrations (geometric mean) rather than by taking the arithmetic mean. This reduces the impact of a few unusually large concentrations. Uranium occurrences were compiled from NURE quadrangle evaluation reports (table 4), and are listed by geologic age, unit, and number of occurrences per 1^o x 2^o quadrangle (table 6). The Brigham City, Salt Lake City, Tooele, Grand Junction, and Cedar City quadrangles are not covered by NURE reports, so no data are available for those quadrangles. Based on uranium concentration (table 5; maximum concentration exceeding 1,000 ppm or mean concentration exceeding 50 ppm) and the number of uranium occurrences (table 6; minimum of 5), geologic units in Utah that are a potential source of uranium-enriched sediment include the Permian Cutler Group and Phosphoria Formation, the Triassic Moenkopi and Chinle Formations, the Jurassic Morrison Formation, the Cretaceous Dakota Sandstone and Mesaverde Group, the Tertiary Uinta Formation, and Tertiary volcanic rocks (figure 1; tables 5 and 6). Other geologic units lacking occurrence and assay data, such as granitic intrusions in the Wasatch Range east of Sandy, may also be local sources of uranium-enriched sediment (Solomon and others, 1991).

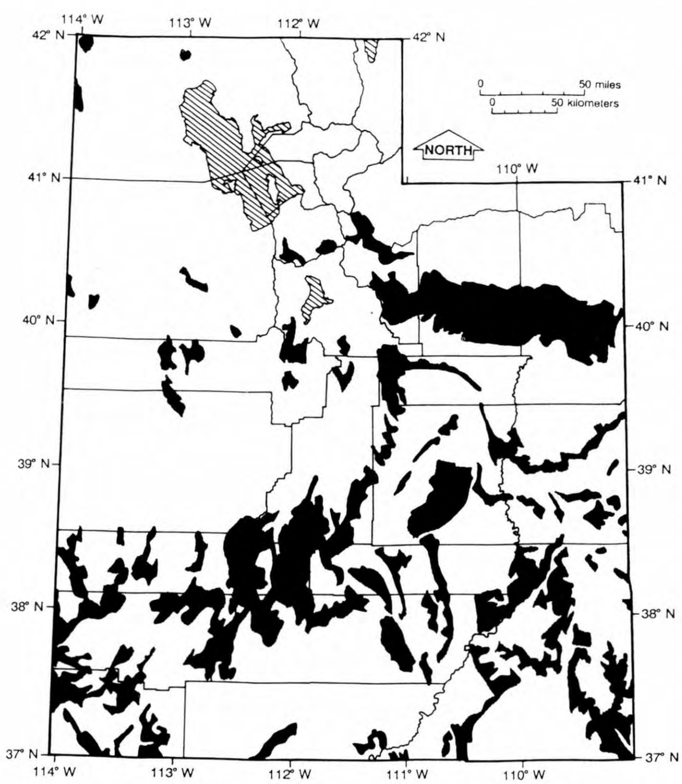


Figure 1. Generalized outcrop pattern (darkened areas) of rock units with a high potential as sources of uranium and uranium-enriched sediment (modified from Hintze, 1975). Areas underlain by uranium-enriched rock and sediment are generally associated with a high indoor-radon potential, although the potential is affected by other factors.

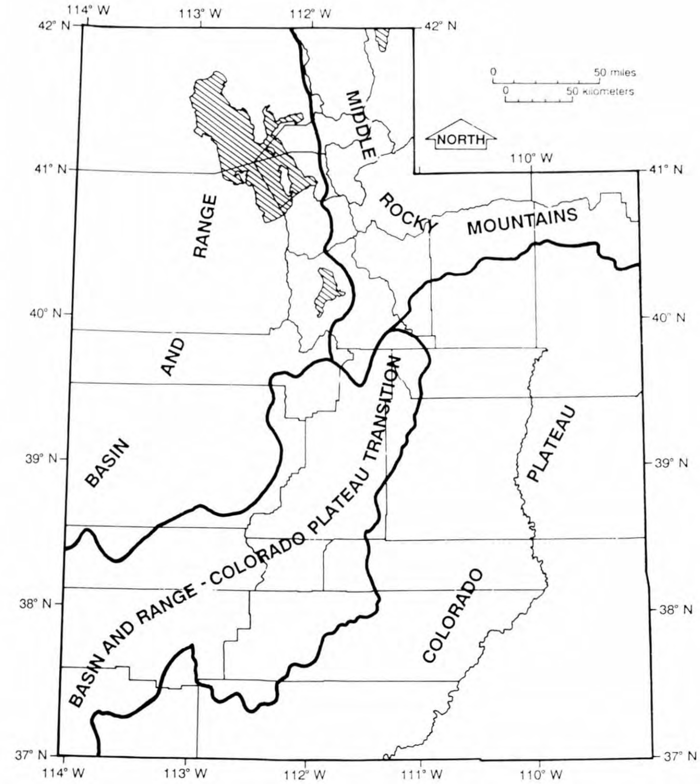


Figure 2. Physiographic subdivisions of Utah (modified from Stokes, 1977).

In the Basin and Range Province and Basin and Range-Colorado Plateau transition zone (figure 2), several intermediate-to-silicic Tertiary volcanic rocks have a high potential as sources of uranium-enriched sediment (tables 5 and 6). Many of these volcanic rocks were prolific producers of uranium ore in Utah. Included are rhyolite flows and ash-flow tuffs of the Mount Belknap volcanics (Cunningham and Steven, 1979); the Osiris Tuff, ash-flow tuffs of the Isom Formation and Needles Range Group, and latite and andesite flows and breccia of the Mount Dutton Formation (Anderson and Rowley, 1975); latite and andesite tuff and breccia of the Bullion Canyon volcanics (Callaghan, 1939); the ash-flow tuff of the Tunnel Spring Tuff (Steven, 1989); and other Tertiary-age pyroclastic and rhyolite flows.

In the Middle Rocky Mountains (figure 2), rocks with a high potential to serve as sources of uranium-enriched sediment are the Permian Phosphoria Formation (McKelvey and others, 1959), the Tertiary Uinta Formation (Dane, 1954), and Tertiary volcanic rocks (tables 5 and 6). The Phosphoria Formation was a producer of low-grade uranium ore in northern Utah (Madson and Reinhart, 1982).

Several rock units have a high potential to serve as sources of uranium-enriched sediment in the Colorado Plateau (figure 2). In addition to the Tertiary Uinta Formation, these include: (1) the Permian Cutler Group (Baars, 1962), (2) the Triassic Moenkopi Formation (Blakey, 1974), (3) the Triassic Chinle Formation (Stewart and others, 1972), (4) the Jurassic Morrison

Formation (Ekren and Houser, 1959), (5) the Cretaceous Dakota Sandstone (Gregory and Moore, 1931), and (6) the Cretaceous Mesaverde Group (Spieker and Reeside, 1925) (tables 5 and 6). Like the Tertiary volcanics, the Chinle and Morrison Formations were also prolific producers of uranium ore.

HAZARD DISTRIBUTION

The Basin and Range-Colorado Plateau transition zone (figure 2) has the highest overall radon-hazard potential in the state. In this province, areas of high hazard potential commonly occur where uranium-enriched Tertiary volcanic rocks are found, such as the volcanic plateaus in south-central Utah. The map shows a significant area of high hazard potential that extends from west of Cedar City northeastward across the Sevier Plateau, and includes the communities of Beaver, Monroe, and Richfield . Other large areas of high hazard potential occur in northwestern Iron County and western Beaver County. Tertiary volcanic rocks and soil derived from them are common throughout all of these areas. Low hazard potential commonly occurs in central parts of valleys, including Cedar, Parowan, Sevier, and Sanpete Valleys, and in the Escalante Desert, where shallow ground water and low permeability soils are found.

The Colorado Plateau Province (figure 2) has a moderate to high radon-hazard potential. Although the hazard potential of the Colorado Plateau is generally restricted by low uranium levels, the San Rafael Swell and Book Cliffs areas are underlain by rock with moderate uranium levels. These areas, including the communities of Price and Green River, have a high radon-hazard potential due to permeable soils and deep ground water. Other areas of high potential are associated with uranium-enriched sedimentary rocks, such as the Chinle and Morrison Formations. These areas generally occur in sparsely populated regions. Areas of low potential are few and mainly occur west of Monticello around the Abajo Mountains and near Escalante.

The Middle Rocky Mountains Province (figure 2) has a generally moderate radon-hazard potential. Like the Colorado Plateau, much of this province has low uranium levels. However, areas with moderate to high uranium levels, such as eastern Rich County (east of Bear Lake) and the Uinta Mountains, have a high radon-hazard potential. Scattered areas of high potential occur in the Wasatch and Bear River Ranges where Tertiary volcanic rocks (volcanic tuffs/breccias and granitic intrusions in the Park City/Alta area) and Precambrian metamorphic rocks (Farmington Canyon Complex in Davis County) are found. Areas of low radon-hazard potential occur in the central part of the Cache Valley and along the Bear and Weber Rivers, where there are shallow ground water and impermeable soils.

The Basin and Range Province (figure 2) has the lowest overall radon-hazard potential. Shallow ground water and impermeable clay-rich soils low in uranium are common in the basins of western Utah, such as the Great Salt Lake Desert and Sevier Lake basin. High radon-hazard potential commonly occurs in mountain ranges, such as the Grouse Creek, Raft River, and Oquirrh Mountains, where soil and ground-water conditions are favorable for indoor-radon hazards. In addition, large portions of the Deep Creek, House, and Confusion Ranges are also high, primarily due to the presence of Tertiary volcanic rocks. Along the Wasatch Front, the benches near the mountain front generally have a moderate to high radon-hazard potential due to favorable soil and ground-water conditions. Tooele Valley is also moderate to high for similar reasons. A low hazard potential occurs in basin bottoms along the margins of Great Salt Lake and Utah Lake.

SUMMARY

Radon is an odorless, tasteless, radioactive gas of geologic origin that is an environmental concern because of its link to lung cancer. Radon can be found in small concentrations in nearly all geologic materials, and has been found in many buildings throughout the United States in sufficient concentrations to pose a health hazard to building occupants.

The level of exposure to the radon hazard depends on both geologic and non-geologic factors and cannot be predicted entirely by geologic means. The effects of geologic factors can be estimated, whereas the effects of non-geologic factors, such as type of construction, weather, and individual lifestyles, are difficult to quantify and characterize regionally. Because of the complex relationship between geologic and non-geologic factors that control radon levels, predicting indoor-radon levels from building to building is difficult even in areas with a high radon-hazard potential.

The radon-hazard potential of Utah has been mapped using three geologic factors: (1) uranium concentration, (2) soil permeability, and (3) depth to ground water. Uranium occurrence and assay data are also shown on the map to indicate areas underlain by rock that may be a source of radon or uranium-enriched sediment. A numerical rating system was used to derive a qualitative assessment of relative radon-hazard potential. In areas of high radon-hazard potential, factors are favorable for elevated indoor-radon levels. In areas of moderate potential, indoor-radon levels may be limited by one or more unfavorable factors. In areas of low potential, factors are generally unfavorable for elevated indoor-radon levels. Field investigations conducted by the UGS show a general correlation with the radon-hazard potential shown on the map; future investigations will attempt to define prospective radon-hazard areas in more detail.

The Basin and Range-Colorado Plateau transition zone has the highest hazard potential, primarily due to uranium-enriched Tertiary volcanic rocks and soil derived from these rocks. The hazard potential in the Colorado Plateau and Middle Rocky Mountains is moderate to high; areas of high potential are due to deep ground water and shallow soils combined with moderate to high uranium levels. The Basin and Range has the lowest hazard potential, primarily due to valley basins in western Utah, where shallow ground-water and impermeable clay-rich soils low in uranium are found. Areas of high potential commonly occur in mountain ranges, where geologic factors are favorable.

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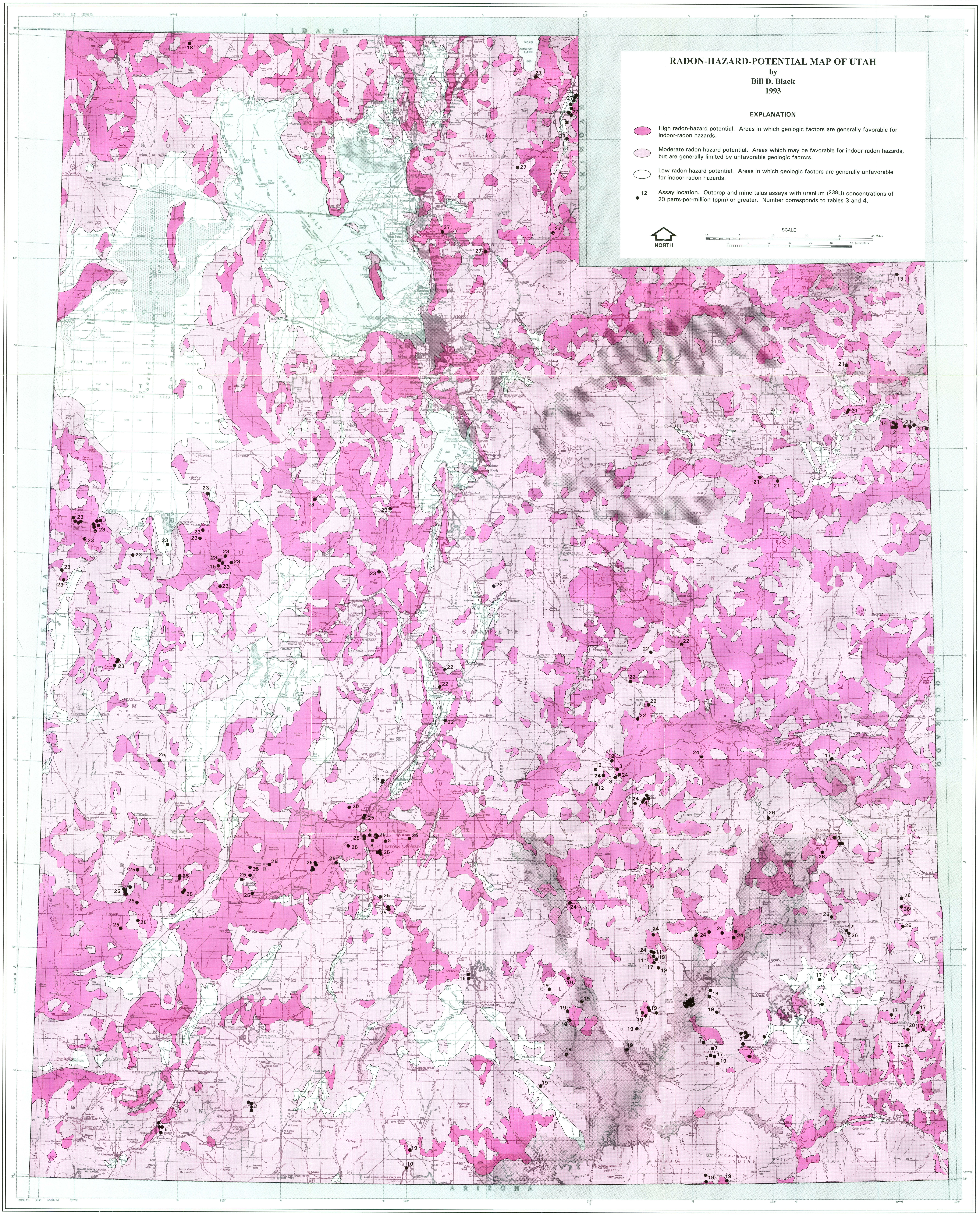

Base map from U.S. Geological Survey, State of Utah, 1988.
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