Minnesota Department of Health
Environmental Health Division
Source Water Protection Unit

Distribution of Radium in Minnesota Drinking Water Aquifers

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Introduction

Radium is a naturally-occurring radioactive metal produced by decay of geologically abundant uranium or thorium. Public water systems monitor radium-226 (^{226}Ra) and radium-228 (^{228}Ra) because ingesting combined radium (^{226}Ra + ^{228}Ra) above the Maximum Contaminant Level (MCL) of 5.0 picocuries per liter (pCi/L) may present increased cancer risk to humans (bone and blood cancers). The presence of radium in source water above the MCL adds expense to public water systems because of the need for treatment or blending. The health and economic difficulties that radium causes can be reduced by understanding factors that control its occurrence.

Studies of radium in groundwater across many parts of North America indicate that southern Minnesota is within a zone where radium is present at high levels (Focazio, et al., 2001). Lively et al., (1992) defined the distribution of radium within the Mt. Simon Aquifer in Minnesota. From 2007-2010, the Minnesota Department of Health (MDH) investigated patterns of radium occurrence in two Cambrian sandstone drinking water aquifers (Mt. Simon and Jordan) beneath southern Minnesota to guide future well-drilling efforts away from radium-producing aquifers and to identify areas where treatment may be required to meet federal drinking water standards. This memorandum summarizes three steps taken to fulfill those objectives: 1) capturing all available radium data (all aquifers) from existing water quality databases; 2) generating new data in selected locations through the sampling of wells completed in the Mt. Simon Aquifer or the St. Peter-Prairie du Chien-Jordan Aquifer system, and 3) mapping the resulting radium distributions. Steps 1 and 2 were carried out in close collaboration with David Vinson (Ph.D. candidate, hydrogeochemistry, Duke University) while he was employed by MDH.

Methods

Database Assembly. The database assembled for this project contains existing data from several sources and new data from recent sampling, to form a radium data set with 819 data points. Data capture from existing databases constituted a significant portion of this project. Existing data sources included: the MDH Minnesota Drinking Water Information System (MNDWIS); Minnesota Geological Survey (Lively et al., 1992); U.S. Geological Survey; and Siegel (1989).

Sampling to Generate New Data. In approximately 100 locations, new data was generated through the sampling of public water supply wells. Sampling consisted of: 1) field measurement of temperature, pH, oxidation-reduction potential, specific conductance, and dissolved oxygen; and 2) collection of untreated water samples for radium, major ions, trace metals, tritium, and bromide. Duke University analyzed most samples for radium isotopes ^{224}Ra, ^{226}Ra, and ^{228}Ra by means of a laboratory method currently being tested. Selected split samples were provided to the MDH Environmental Laboratory for radium analysis by means of the standard U.S. Environmental Protection Agency method for ^{226}Ra and ^{228}Ra.

Results

Radium distribution (^{226}Ra, ^{228}Ra, combined radium, and the radium isotope ratio ^{228}Ra/^{226}Ra) in several aquifer systems are discussed below in descending stratigraphic order, and shown on the attached figures.

Quaternary Aquifer. Figure 1 shows the statewide distribution of combined radium in public drinking water supply wells completed in Quaternary Aquifers. Although data density was low (162 data points), a pattern of generally low combined radium was evident. Four wells (2.5%) exceeded the combined radium MCL, and all are within the Des Moines Lobe footprint.

St. Peter-Prairie du Chien-Jordan Aquifer System. Figures 2 through 5 show radium distribution in the St. Peter-Prairie du Chien-Jordan Aquifer system. Figure 2 indicates that, due to the presence of ^{226}Ra alone, 19 wells (4.6%) exceeded the combined radium MCL. On the other hand, ^{228}Ra alone (Figure 3) rarely exceeded 3 pCi/L, and there was little spatial variability. Combined radium (Figure 4) is highly variable, and wells that exceeded the MCL were located in Hennepin County, southern Ramsey County, and in a belt extending southward through Rice and northern Steele Counties. Elsewhere, combined radium measurements were generally low. Forty-eight wells (12.4% of those sampled) exceeded the radium MCL. However, the data density was uneven and included a large number of wells in low-radium areas (Washington County, for example).

The ^{228}Ra/^{226}Ra isotope ratio (Figure 5) is sensitive to the natural radium source in each aquifer derived from thorium and uranium. Because uranium is released to groundwater under oxidizing conditions and thorium is relatively insoluble, low isotope ratios (<1.0) suggest post-depositional uranium enrichment and high isotope ratios (>1.0) suggest post-depositional uranium depletion. The mean ^{228}Ra/^{226}Ra isotope ratio was 0.86, and the greatest isotope ratios (>1.50) occurred where overlying bedrock confining layers (Decorah-Platteville-Glenwood) were absent.

Franconia-Ironton Galesville Aquifer System (CFIG). Due to data scarcity, radium in the Franconia-Ironton-Galesville Aquifer system is unmapped. Descriptive statistics (Table 1) indicate radium is generally below the MCL. Data density is poor where high radium is found in other aquifers.

Table 1: Descriptive Statistics, Radium in Franconia-Ironton-Galesville Aquifer

	Minimum	Maximum	Mean	Std. Dev.
^{226}Ra (*41*)	0	4.80	0.95	1.31
^{228}Ra (*41*)	0	4.33	1.32	1.19
^{226}Ra + ^{228}Ra (*40*)	0	9.05	1.86	2.50

Units: pCi/L
Number of analyses for each analyte indicated in parentheses.

Mt. Simon Aquifer. This study's findings for the Mt. Simon Aquifer are similar to those described in Lively et al. (1992). Figures 6 through 9 show radium distribution in the Mt. Simon Aquifer. Figure 6 indicates that, because of the presence of ^{226}Ra alone, 29 wells (21%) exceeded the radium MCL. Figure 7 indicates that, due to ^{228}Ra alone, 45 wells (32.6%) exceeded the radium MCL. Both ^{226}Ra and ^{228}Ra varied widely in a complex spatial pattern. Combined radium (Figure 8) generally approached or exceeded the MCL, sometimes by a great margin (maximum value 34.2 pCi/L; mean value 8.23 pCi/L). The ^{228}Ra/^{226}Ra isotope ratio (Figure 9) was generally greater than 1.0 (mean value 1.49), and varied widely in a complex pattern, decreasing from south to north.

References

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Lively, Richard S., Jameson, Roy, Alexander, E.C., Jr., and Morey, G.B., et al., (1992), *Radium in the Mt. Simon-Hinckley aquifer, east-central and southeastern Minnesota*, Minnesota Geological Survey Information Circular 36, 58 pp.

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Figure 1: Combined Radium Quaternary Aquifers of Minnesota

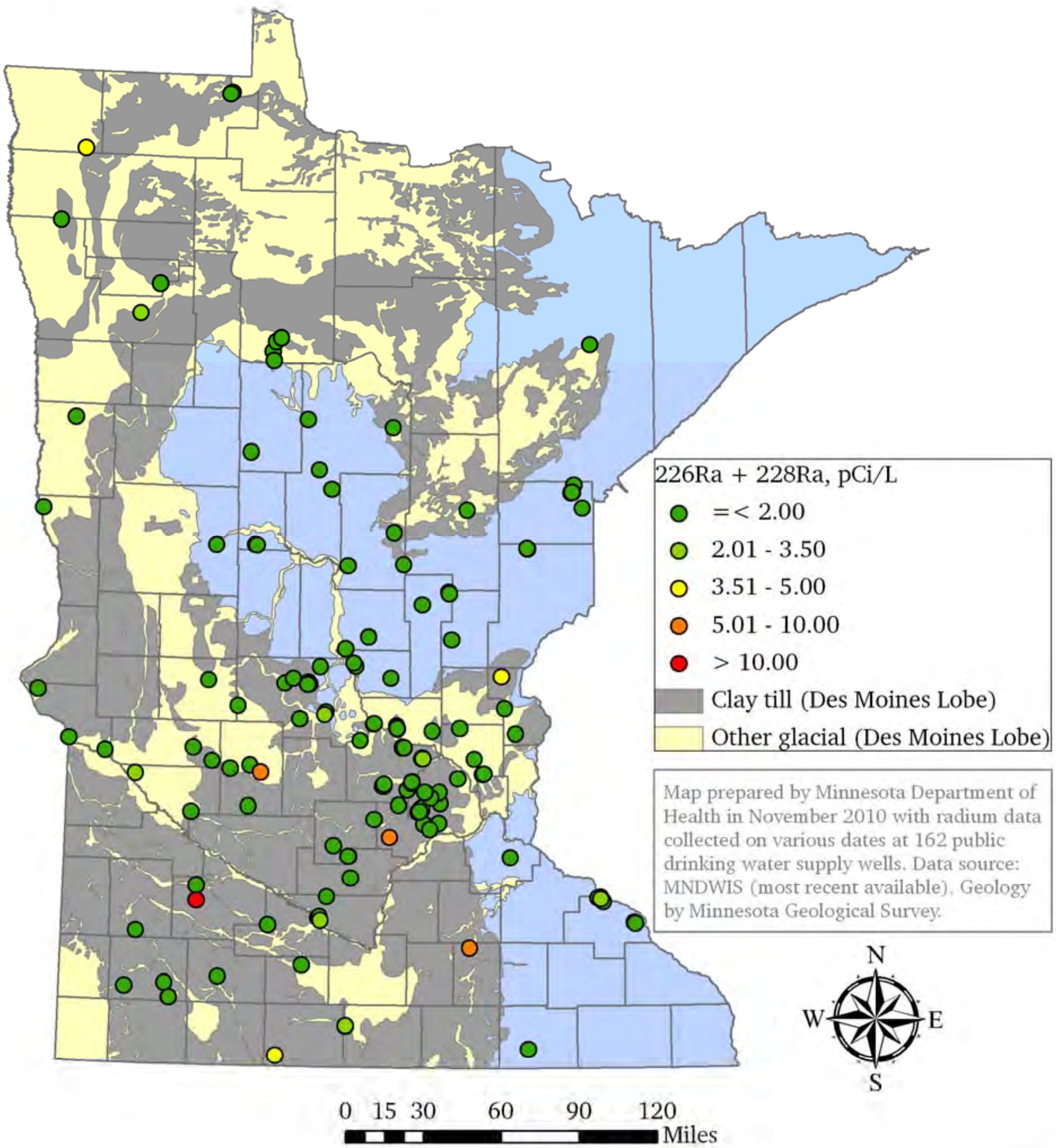

Figure 2: Radium 226 Distribution in the St. Peter-Prairie du Chien-Jordan Aquifer System

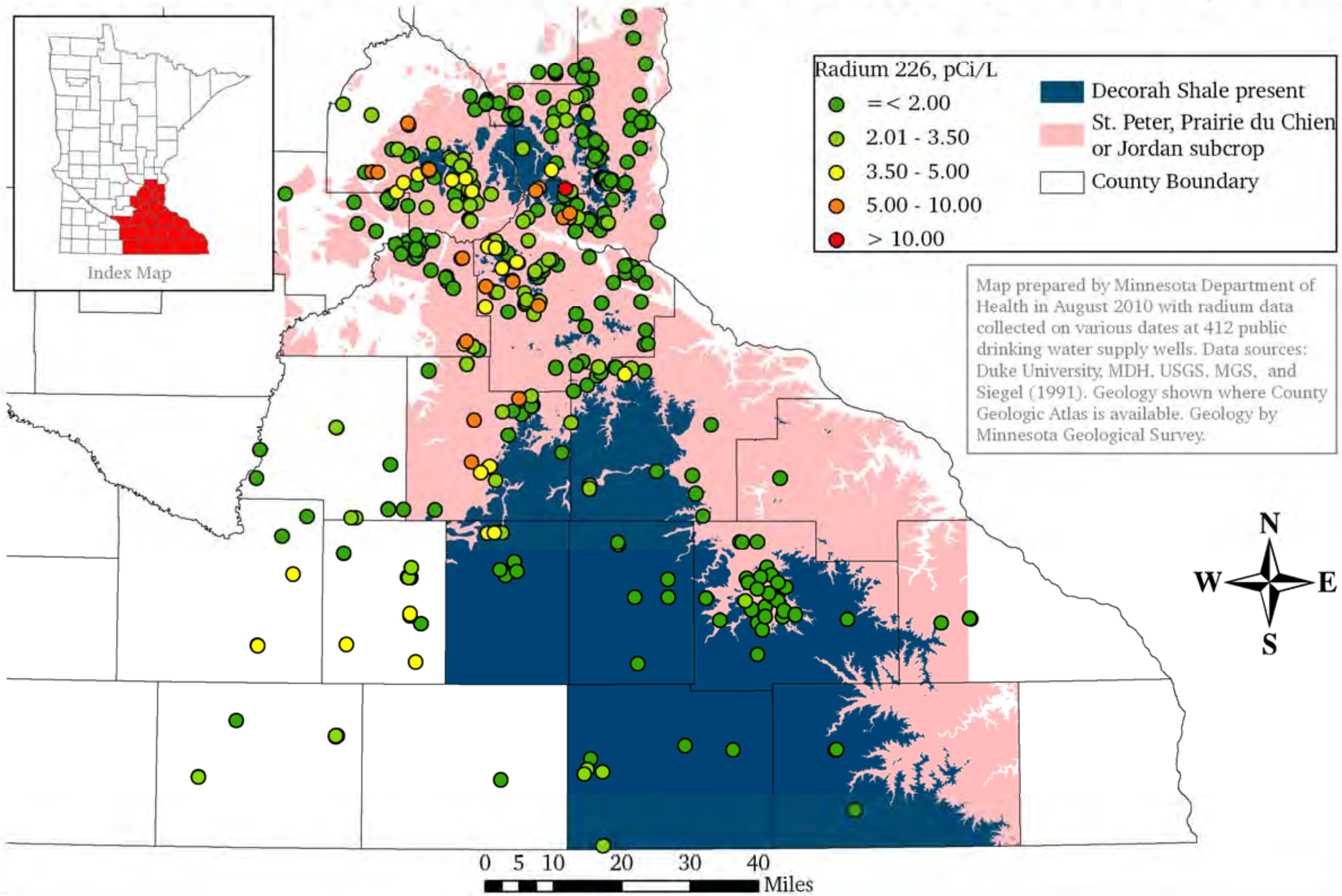

Figure 3: Radium 228 Distribution in the St. Peter-Prairie du Chien-Jordan Aquifer System

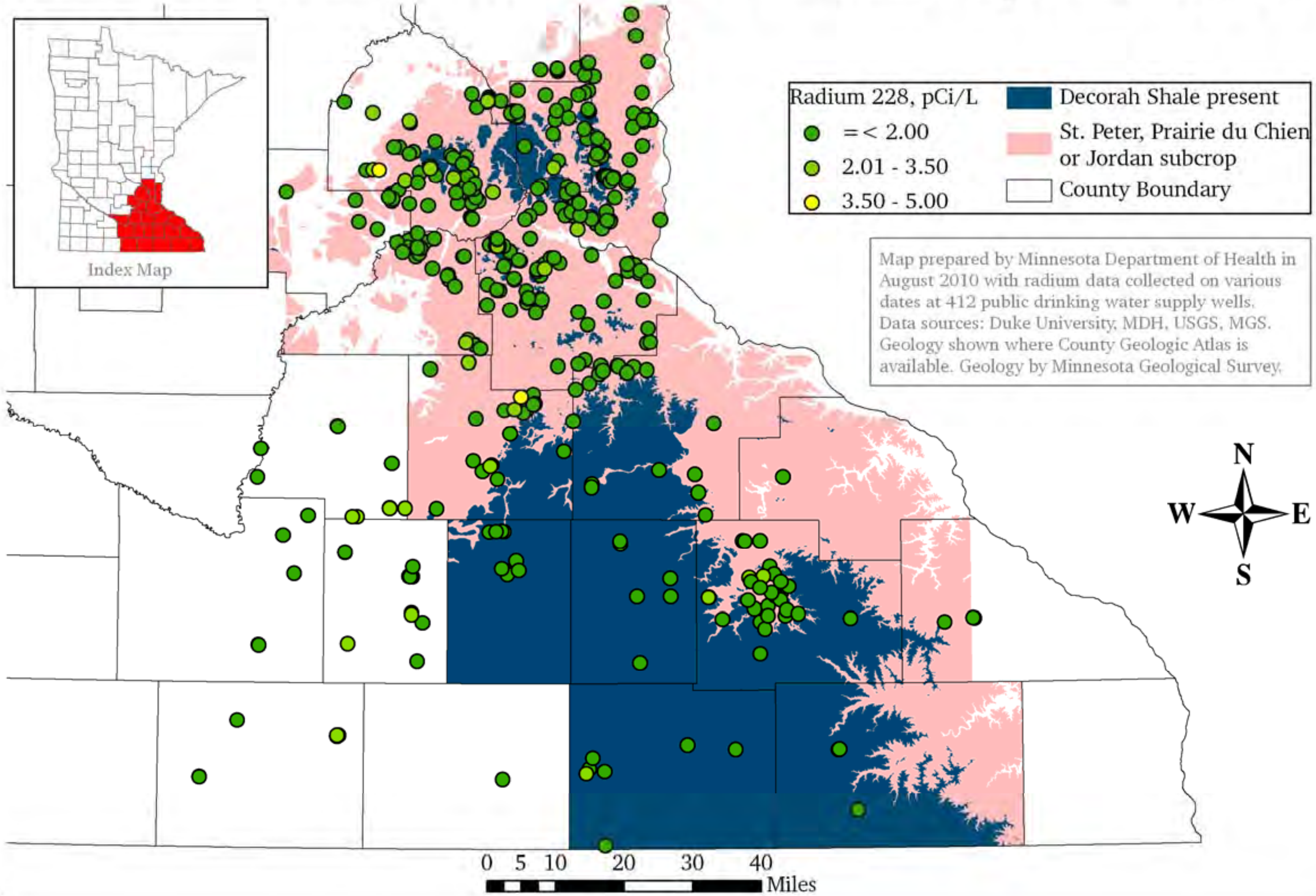

Figure 4: Combined Radium Distribution, St. Peter-Prairie du Chien-Jordan Aquifer System

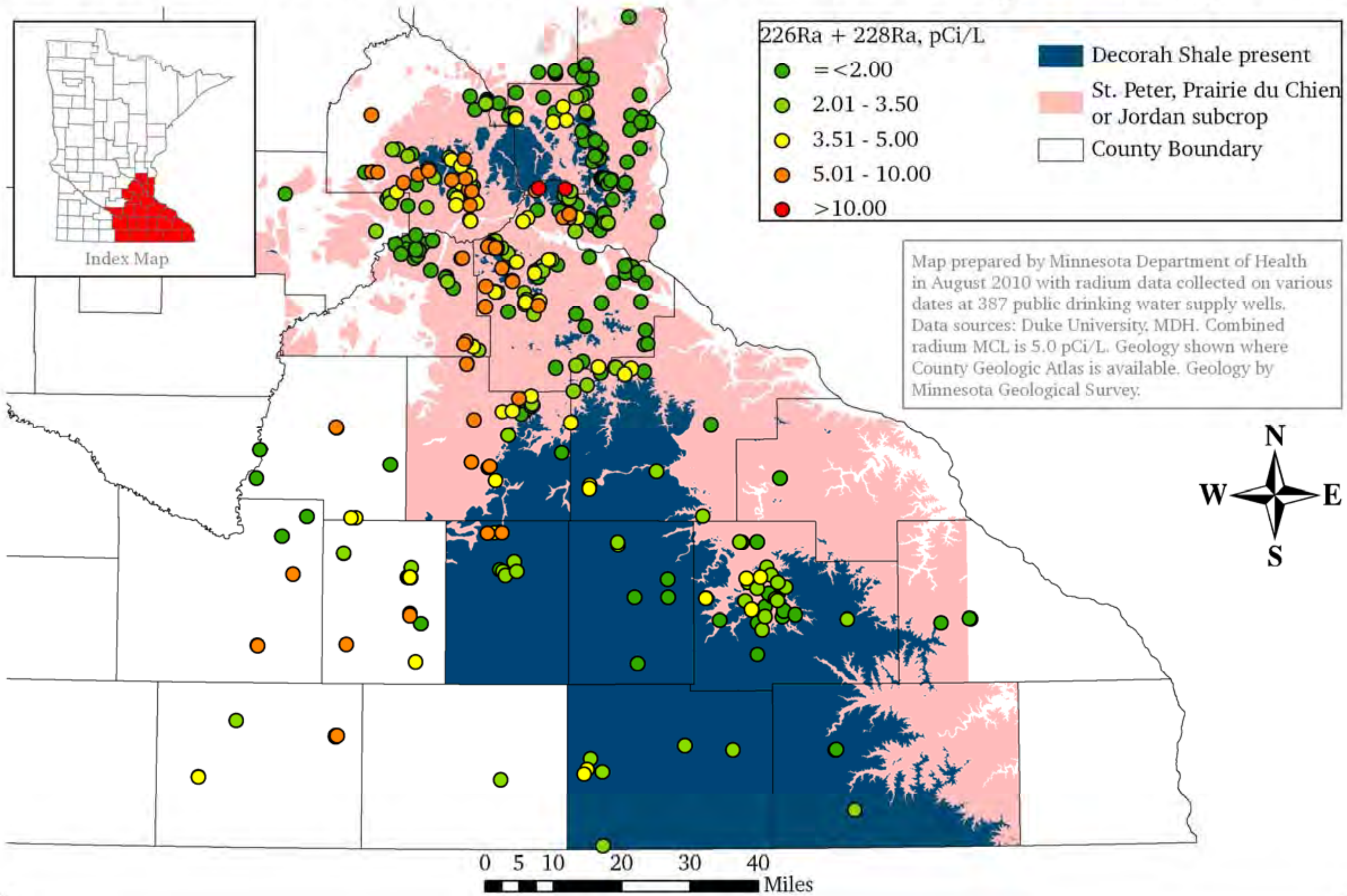

Figure 5: 228Ra/226Ra Distribution, St. Peter-Prairie du Chien-Jordan Aquifer System

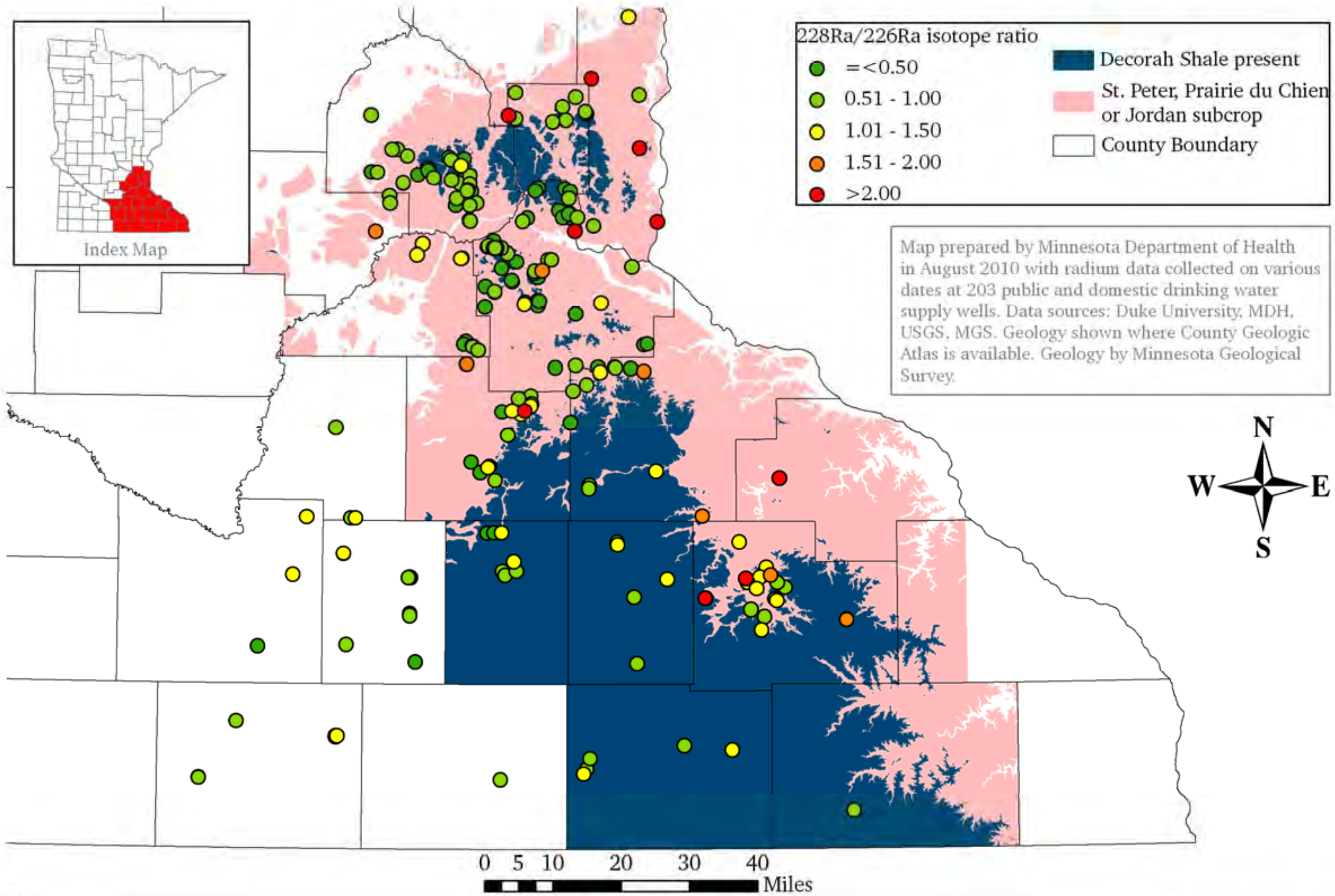

Figure 6: Radium 226 Distribution in the Mt. Simon Aquifer

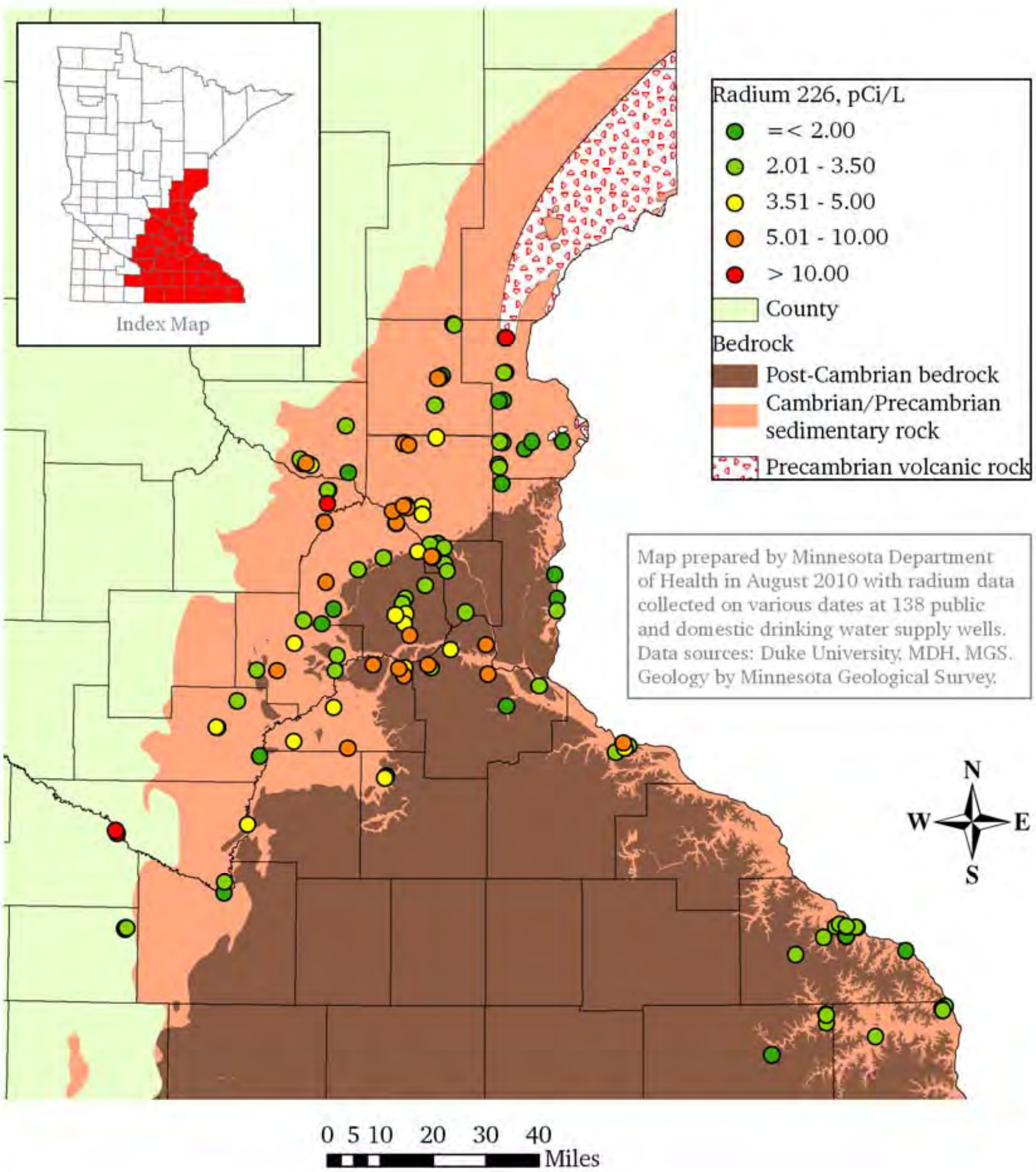

Figure 7: Radium 228 Distribution in the Mt. Simon Aquifer

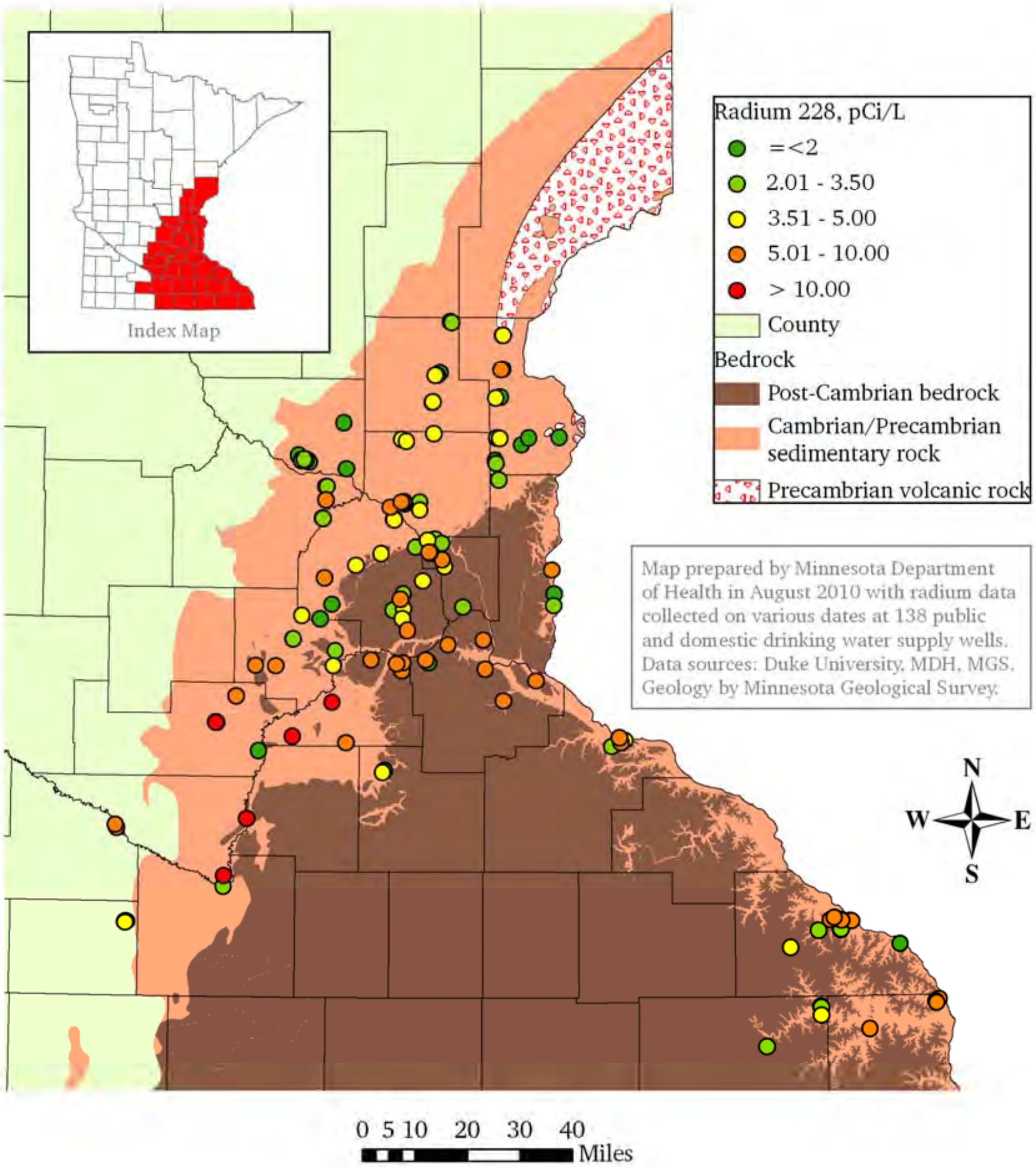

Figure 8: Combined Radium Distribution Mt. Simon Aquifer

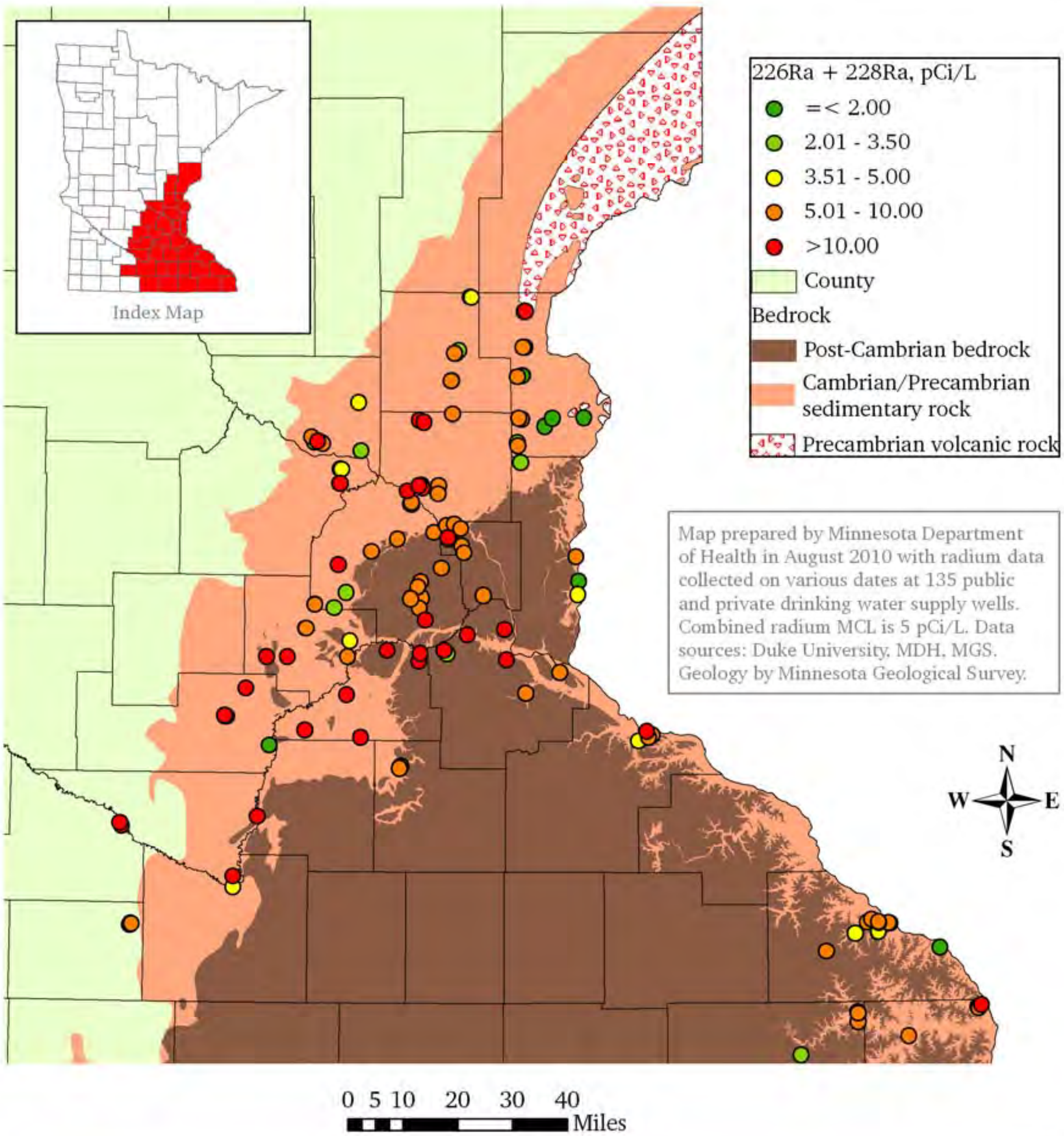

Figure 9: 228Ra/226Ra Isotope Ratio Distribution, Mt. Simon Aquifer