URANIUM DISTRIBUTION IN SEDIMENTS OF THE UPPER SAN PEDRO BASIN, SOUTHEAST ARIZONA, AND IMPLICATIONS FOR INDOOR RADON

by

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INTRODUCTION

Radon is a colorless, odorless gas produced by the natural radioactive decay of uranium. The U.S. Environmental Protection Agency has determined that exposure to indoor radon may increase a person's risk of developing lung cancer. Indoor-radon levels generally correlate with uranium concentration in underlying rocks and soil, and some areas of Arizona are known to have elevated levels of uranium.

This study is part of an ongoing evaluation of potential radon hazards in Arizona by the Arizona Geological Survey and the Arizona Radiation Regulatory Agency. This report presents results of a study of the distribution of uranium in late-Cenozoic basin-fill sediments of the upper San Pedro valley in southeast Arizona.

Uranium concentrations were measured using a portable gamma-ray spectrometer. The spectrometer survey followed the methods outlined in Duncan and Spencer (1993) and the same equipment was used during both investigations. Indoor-radon data were supplied by the Arizona Radiation Regulatory Agency and well water-radon data were taken from Duncan et al. (1993).

LOCATION

The San Pedro basin is a large, elongate valley in southeast Arizona, extending from northern Sonora, Mexico north-northwest for more than 150 miles to Kelvin, Arizona (figure 1). The valley is drained by the San Pedro River, a permanent stream, which flows north to Winkleman, where it joins the Gila River, which flows northwest to Kelvin.

This study focuses on the upper portion of the San Pedro basin, defined here as that part of the valley south of an area known as The Narrows, corresponding to the eastern edge of the Little Rincon Mountains. The upper San Pedro Valley includes the towns of Pomerene, Benson, Saint David, Huachuca City, Tombstone, Palominas, Nicksville, Fort Huachuca, and Sierra Vista.

GEOLOGY

Upper San Pedro Basin

The San Pedro basin is an extensive structural trough, 2 to 10 miles wide and over 120 miles long in Arizona (the trough continues into Sonora, Mexico), formed during the late-Tertiary Basin and Range disturbance. The upper basin is bordered on the east side by the Mule Mountains, Tombstone Hills, Dragoon and Little Dragoon Mountains, and Johnny Lyon Hills and on the west side by the Huachuca, Whetstone, Rincon and Little Rincon Mountains. An extensive variety of rock types are found in the bordering mountains, including Precambrian metamorphic and granitic rocks, Paleozoic and Mesozoic sedimentary rocks, Jurassic volcanic rocks, and mid-Tertiary silicic volcanic and plutonic rocks.

A thick sequence of mid- to late-Tertiary sediments was deposited in the basin. The sediments consist of alluvial and fluvial silt, sand, and gravel interfingered with lacustrine deposits. Gravity modelling indicates that basin-fill sediments may be nearly 3200 feet thick near Benson and up to 4800 feet thick southeast of Sierra Vista (Oppenheimer, 1980).

The lowest stratigraphic unit exposed in the study area is the St. David Formation, divided into three members by Gray (1965, 1967). Fine sand, silt, and red clay, commonly gypsiferous, comprise the lower member. Although the base is not exposed, well logs indicate at least 1000 feet of additional fine-grained sediments (Gray, 1965).

The middle member of the St. David Formation consists of red to green clay, marl, water-laid tuffs and minor sand and gravel. Lacustrine conditions prevailed during much of the

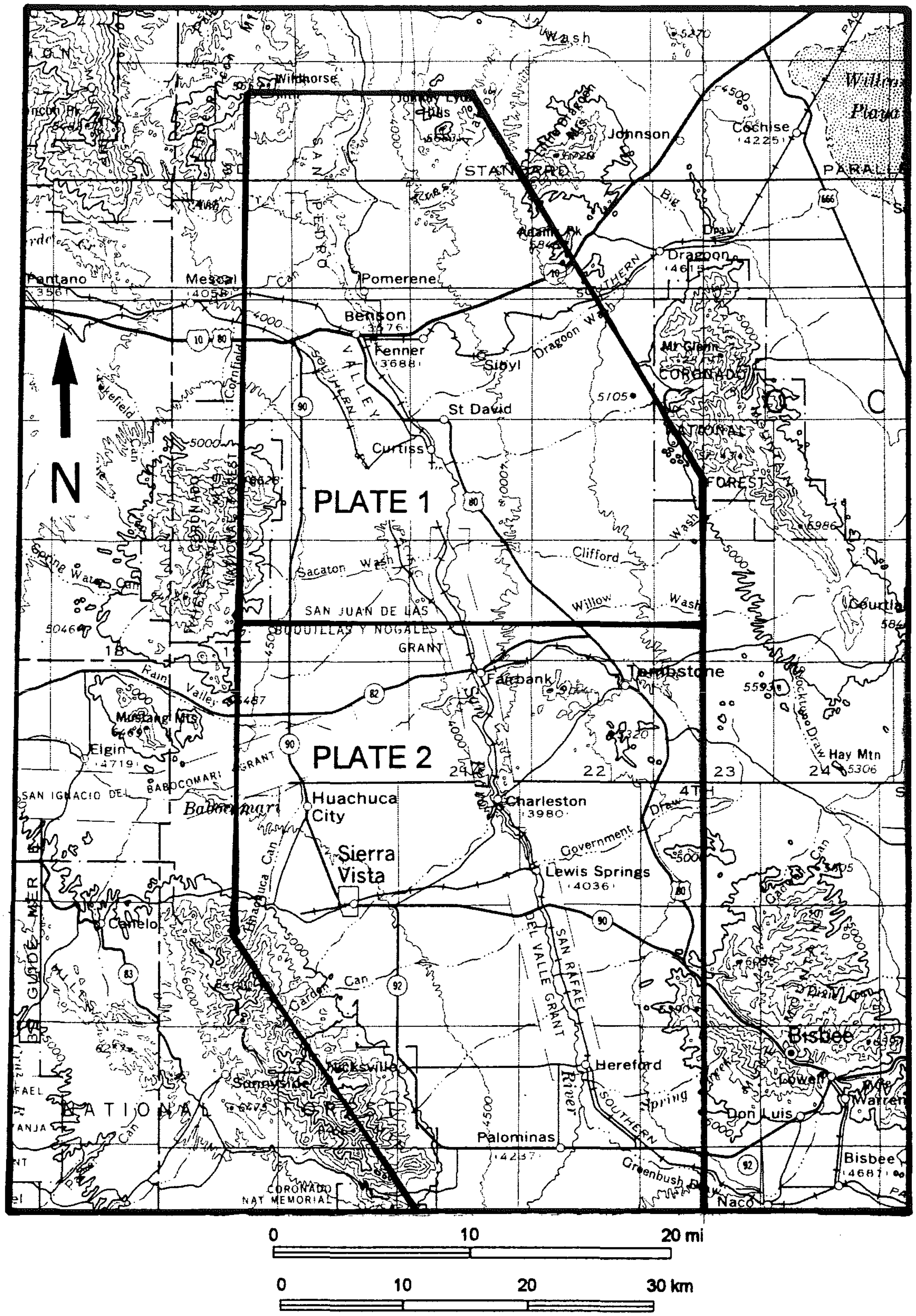

Figure 1. Location of study area. Outlined areas show coverage of plates 1 and 2.

deposition of the middle member. Johnson and others (1975) have dated the boundary between the lower and middle members at about 3.4 Ma.

Coarser sediments characterize the upper member of the St. David Formation, with brown to orange silts, sands, and gravels predominant over clay. Calcareous paleosols are common throughout the middle and upper members. Disconformably overlying the St. David Formation are mid-Pleistocene sand and gravel deposits, termed "granite wash" by Gray (1965).

Detailed investigations of the basin-fill sediments were conducted by Gray (1965, 1967), D.G. Smith (1963), Montgomery (1963), Johnson et al. (1975), Lindsay, et al. (1990a), and G.A. Smith (1994). Paleontological studies include Harrison (1972), Lammers (1970), Lindsay, et al. (1990b), and Haynes (1968). Uranium occurrences and favorability were surveyed by Scarborough (1981) and Luning and Brouillard (1982).

GAMMA-RAY SPECTROMETER SURVEY

Methods

The Arizona Geological Survey conducted a survey of the San Pedro basin using an EG&G geoMetrics model GR-310 portable gamma-ray spectrometer. The machine employs an external detector containing a 347-cm^3, thallium-doped, sodium iodide crystal and a high-gain photomultiplier tube. Four independent channels provide measurements of the diagnostic gamma radiation for uranium (via bismuth-214, 1.76 million electron volts [MeV]), thorium (via thallium-208, 2.62 MeV), which is needed for uranium assay corrections, as well as total gamma radiation (0.4 to 4.0 MeV) and potassium.

Count times of 1, 10, 100, or 1000 seconds may be selected, and due to the random nature of radioactive decay, longer count times generate less statistical error and greater precision. Periodic comparisons of 100- versus 1000-second count times confirmed that the shorter count time was sufficiently accurate for the purposes of this study and so was used for data acquisition. Uranium concentrations in parts per million (ppm) were calculated from the field data using correction factors and assay equations developed by Duncan and Spencer (1993).

Results

Locations of spectrometer measurements and uranium concentrations are shown on plates 1 and 2. Figure 2 is a histogram of uranium concentrations determined by spectrometer measurements. The mean for 443 samples in the San Pedro basin is 2.50 ppm. Uranium concentrations greater than 6 ppm are considered anomalous (Duncan and Spencer, 1993). No anomalous concentrations of uranium were measured in any sediments in this study.

URANIUM GEOLOGY

Rock-type Associations

Uranium anomalies in the sediments of late-Cenozoic basins in Arizona are generally restricted to marly, diatomaceous, and cherty lacustrine sediments. These types of uranium-bearing sediments have been described in the Verde Valley (Duncan, 1993) and in the Safford-San Simon and Duncan valleys (Harris, 1994). The basin fill of the upper San Pedro Valley contains only minor marly and diatomaceous lacustrine sediments and no anomalous levels of uranium were found in these lacustrine deposits. The sandy to gravelly sediment that forms the bulk of the basin-fill is similarly lacking in uranium.

A U.S. Department of Energy survey (Luning and Brouillard, 1982) failed to find any

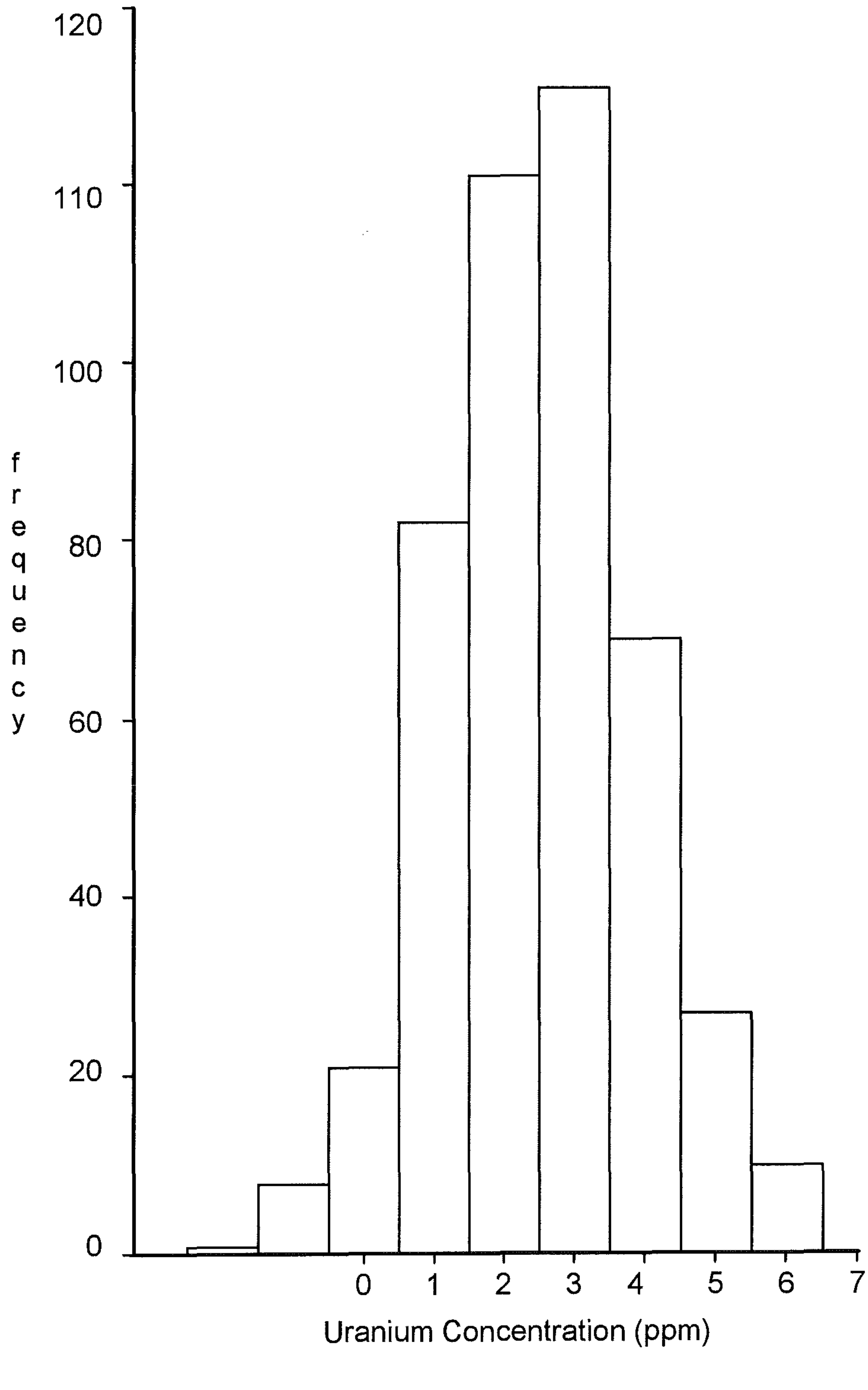

Figure 2. Histogram of uranium concentrations in the upper San Pedro basin. Concentrations greater than 6 ppm are considered anomalous. Values less than zero reflect error introduced during mesurement and calculation of concentration (Duncan and Spencer, 1993), and reveal an accuracy of measurement of probably ± 2-3 ppm.

areas within the valley favorable for uranium accumulation, largely owing to the oxidized nature of the sediments. Uranium concentrations in the bedrock of the surrounding mountain ranges are generally within the range of normal crustal abundances (2 to 4 ppm) with the exception of the Stronghold Granite in the Dragoon Mountains, which contains about 11 ppm uranium. However, granitic alluvium derived from the Dragoons contains less than 6 ppm uranium at all locations sampled in this study).

The only known uranium occurrences near the area of this study are at the north end of the Whetstone Mountains, in the form of small shear zones in Precambrian granite (Atomic Energy Commission, 1970; Scarborough, 1981). The granite adjacent to the shears contains normal levels of uranium, and alluvium derived from the granite is almost devoid of uranium.

Origin of Uranium Anomalies

The concentration of uranium in basin fill is probably more strongly controlled by the nature of the sediments than the amount of influx of uranium. Some of the sediments in the valley were deposited in lacustrine or paludal (swampy) environments. These conditions promote the deposition of fine-grained sediments, including carbonate, diatomite, and organic matter.

Although most carbonate rocks contain very little uranium, especially those deposited in oxidizing environments, some impure carbonates can contain considerably more uranium. Impurities such as clay, organic matter, and silica gel can absorb uranium (Jones, 1978; Schmidt-Collerus, 1979). Tuffaceous sediments may be altered to clay and release silica shortly after deposition, providing sites for uranium adsorption (Zielinski, 1980).

Organic matter in the basin sediments would also contribute to an increased uranium content by reducing the soluble, oxidized form of uranium U(+6) to the insoluble U(+4) state. The presence of organic matter may increase the uranium content by a factor of 10,000 or more over that of the surface runoff or groundwater supplying uranium to the basin (Schmidt-Collerus, 1979).

Conditions during or after deposition of the sediments (at least those presently exposed) in the upper San Pedro basin were apparently not favorable for the accumulation or preservation of uranium. Oxidizing conditions at the time of deposition would have prevented the preservation of organic matter which facilitates the precipitation of uranium, while oxidizing conditions at the present may increase the mobility of uranium, flushing it out of the surficial sediments, resulting in the low concentrations encountered in this study.

Another factor that may account for the lower uranium content of the sediments in the upper San Pedro valley compared with the Safford-San Simon, Duncan, and Verde valleys is the relative scarcity of silicic Tertiary volcanic rocks in the mountains surrounding the upper San Pedro Valley. Weathering of silicic volcanic rocks would contribute silica (and uranium) to the shallow lakes occupying the basins and silica-rich water is necessary for diatoms to flourish. Anamalous concentrations of uranium have been found in many diatomites in Arizona. The upper San Pedro sediments are distinctly less diatomaceous than sediments in many other basins, which may reflect water with less silica available for diatoms.

Correlation with Indoor-radon levels

A residential indoor-radon testing program was performed by the Arizona Radiation Regulatory Agency from 1987 to 1989. The U.S. Environmental Protection Agency has set a guideline indoor radon limit of 4 picocuries per liter (pCi/l), above which mitigation is recommended. Charcoal canister results from 74 homes in the upper San Pedro valley show a mean indoor radon level of 2.27 pCi/l, roughly twice the average of about 1 pCi/l for all of Arizona. Twenty eight homes (38%) registered at or below 1.0 pCi/l; 13 homes (18%) had radon levels higher than 4.0 pCi/l, compared with 5.4% of homes statewide. Eight homes registered more than 8 pCi/l, with the highest reading being 9.7 pCi/l in the Saint David area.

Studies have shown that water may be a significant source of radon in the home, with up to one third of indoor radon coming from water usage, particularly showers (U.S. Department of Energy, 1993). A survey of five water wells in the Sierra Vista area (Duncan et al., 1993) found levels of 886 to 1220 pCi/l radon. The Sierra Vista average is 986 pCi/l, compared to a mean of 1148 pCi/l for 32 wells sampled statewide by Duncan et al. (1993) and 1435 pCi/l for 11 wells sampled statewide by Longtin (1988). Thus, the contribution to indoor radon from water in the Sierra Vista area may be less significant than for other areas of the state, and thus does not provide an explanation for the high average indoor radon in the upper San Pedro Valley.

RECONNAISSANCE OF URANIUM AND RADON IN THE DOUGLAS AREA

The southern portion of the Sulphur Springs Valley was surveyed in this study to confirm low indoor-radon levels found in the states's residential screening program. Fifteen homes in the Douglas area were tested and the average level of radon was 1.43 pCi/l, compared to the state average of 1.6 pCi/l, and 2.27 pCi/l for homes in the San Pedro Valley. None of the homes in Douglas had radon levels exceeding 4 pCi/l, compared with 5.4 percent of homes statewide.

Arroyo downcutting is much less developed in the Sulphur Springs Valley compared with other basins in southern Arizona and thus exposure of older basin-fill sediments is very poor. A maximum of about 12 feet of lacustrine sediment is exposed along Whitewater Draw, an ephemeral wash that is the main drainage of the southern Sulphur Springs valley. Spectrometer measurements of sediments in the valley yielded no levels of uranium over 4 ppm, with an average of 2.0 ppm. A lacustrine gypsum deposit on the north flank of "D Hill", 3 miles east of Douglas, contained virtually no uranium.

CONCLUSION

The upper San Pedro valley contains no known occurrences of anomalous uranium levels in the exposed basin-fill sediments. Levels of uranium average 2.5 ppm, compared to an average level of 1.6 ppm determined in a statewide survey (Duncan and Spencer, 1993).

Homes tested for indoor radon in the upper San Pedro valley have levels above the average for homes statewide, whereas water wells near Sierra Vista, on average, have less radon than the state mean. However, considering the widespread distribution of lacustrine sediments in the basin, exposed and in the subsurface, the basin fill is a potentially significant source of indoor radon derived from water wells. In addition, the possibility exists that small or low-level uranium anomalies are present that were not found during this survey.

In general, however, anomalous uranium levels do not characterize the late-Cenozoic sediments of the upper San Pedro Valley, and highly anomalous indoor radon levels (> 10 pCi/l) are not expected. Measured indoor radon levels are greater than would be anticipated from this study, and are probably due to radon derived from well water or to presently unknown aspects of home design, construction, and ventilation. Study of these topics is more likely to reveal the cause of anomalous indoor radon levels than are further geologic studies.

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