Technical Note
ORP/LV-76-4

REPORT OF AMBIENT OUTDOOR RADON AND INDOOR RADON PROGENY CONCENTRATIONS DURING NOVEMBER 1975 AT SELECTED LOCATIONS IN THE GRANTS MINERAL BELT, NEW MEXICO

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Gregory G. Eadie*
Robert F. Kaufmann*
David J. Markley**
Roosevelt Williams*

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*OFFICE OF RADIATION PROGRAMS - LAS VEGAS FACILITY
U.S. ENVIRONMENTAL PROTECTION AGENCY
LAS VEGAS, NEVADA 89114

**U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION VI, DALLAS, TEXAS

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DISCLAIMER

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PREFACE

The Office of Radiation Programs of the U.S. Environmental Protection Agency carries out a national program designed to evaluate population exposure to ionizing and nonionizing radiation, and to promote development of controls necessary to protect the public health and safety. This report describes a survey conducted in the Grants Mineral Belt area of New Mexico to evaluate the ambient outdoor radon and indoor radon progeny concentrations. Readers of this report are encouraged to inform the Office of Radiation Programs of any omissions or errors. Comments or requests for further information are also invited.

Donald W. Hendricks

Donald W. Hendricks
Director, Office of
Radiation Programs, LVF

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SUMMARY AND CONCLUSIONS

This report presents the results of measurements of ambient outdoor radon[1] concentrations and indoor radon progeny working level determinations during November 1975 for 10 locations throughout the Ambrosia Lake area and vicinity, New Mexico. For that portion of the study area in the vicinity of uranium mines and mills, statistical evaluation of the data indicates that ambient outdoor radon concentrations and the indoor radon progeny levels (WL) are in excess of typical background levels. Better definition of background levels and a more thorough evaluation of specific source terms in the immediate Ambrosia Lake area is strongly suggested. For locations in proximity to a uranium mill site, gamma radiation exposure rates and the radium-226 content of surface soils are also above normal background conditions. This may reflect the deposition of windblown tailings and/or ore dust. To assure compliance with State and Federal regulations, it is recommended that further studies be conducted over at least a one-year period for comparison to the applicable radiation protection guides for those areas in the vicinity of uranium mill sites. Radiation exposures to the general population occupying areas in the immediate vicinity of uranium mining and milling operations should also be evaluated.

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1. The term "radon" is used in this report to designate the radionuclide radon-222.

RECOMMENDATIONS

Analysis of the data generated in this report indicates several problem areas which should be resolved if the environmental effects of uranium mining and milling operations are to be understood. Therefore, the following recommendations for additional studies include evaluations of the ambient radon concentrations, radon progeny working level determinations, radiation surveys, and airborne particulate measurements.

1. Source term identification in the Ambrosia Lake region should be completed. Included in these studies should be radon in effluent discharges from milling operations, mine ventilation and ion exchange plant operations; and radon exhalation from ore stockpiles at the mines and mills, tailings ponds and piles, and natural uranium-bearing formations.

2. In conjunction with the source term identification, careful evaluation of the local area background radon concentrations is necessary.

3. Better definition of area background conditions prior to the initiation of active mining and/or milling operations should be completed for any proposed mining or milling area so that pre-operational baseline conditions can be established. Such areas include San Mateo, Churchrock, and the area east of Moquino where a mill and mine are under development.

4. Long-term sampling (minimum of one year) to determine any seasonal variations and to allow annual averaging for comparison to applicable State and Federal regulations should be considered. The need for additional or continuous environmental monitoring and/or revision of discharge limitations could then be based on these data.

5. The ultimate goal of all the above environmental studies should be a thorough evaluation of population exposures due to uranium mining and milling operations.

INTRODUCTION

At the request of the New Mexico Environmental Improvement Agency (NMEIA), through the U.S. Environmental Protection Agency-Region VI, the Office of Radiation Programs - Las Vegas Facility (ORP-LVF) conducted a survey during November 1975 to evaluate the ambient radiological air quality in the Ambrosia Lake area of New Mexico.

The Ambrosia Lake area is in the central part of the extensive (4,400 km^2) Grants Mineral Belt. It contains three active uranium mills, one inactive mill site, and numerous active underground mines. Figure 1 shows the study area which includes the cities of Grants and Milan on the east, San Mateo on the north, and the villages of Bluewater and Thoreau on the west. This study was designed to provide preliminary information on the degree of airborne radiological contamination in the entire Ambrosia Lake area, rather than identifying specific source terms and their resultant effects.

November was chosen as a month representative of wintertime inversion conditions throughout the Ambrosia Lake region. It was postulated that radon progeny working levels would be near maximum values since the radon would be "trapped" under the inversion layer allowing the radon progeny to achieve relatively high equilibrium concentrations. Maximum indoor radon progeny concentrations were also expected as a result of this inversion layer source term coupled with the reduced indoor air ventilation rate of the heating system versus the "open-air" cooling of summertime.

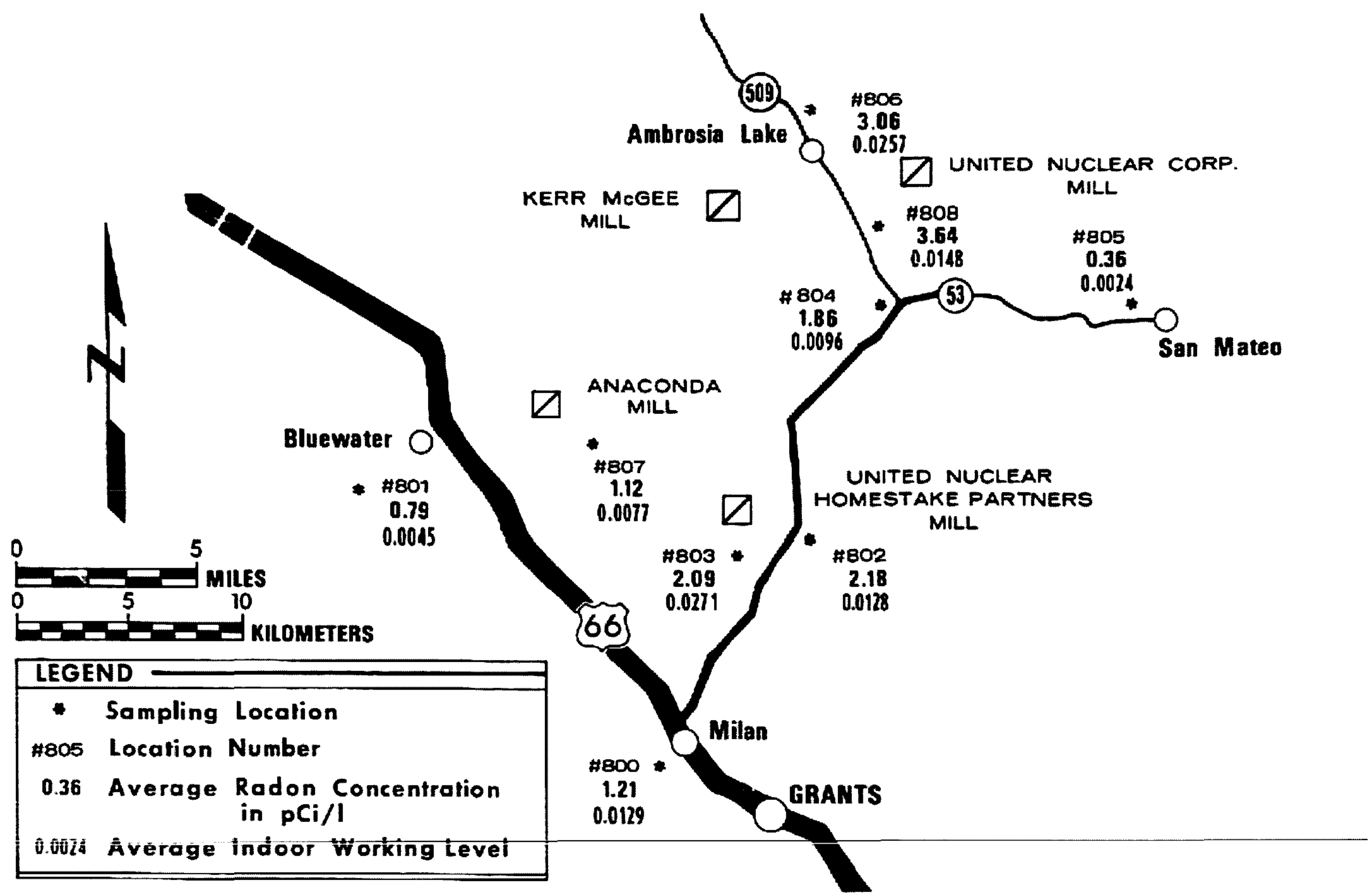

FIGURE 1. GENERALIZED MAP OF SAMPLING LOCATIONS AND SUMMARY OF RESULTS

TYPES OF SURVEYS

RADIATION SURVEYS

Radiation surveys, radioactivity in soils analyses, ambient outdoor radon levels, indoor radon progeny concentrations (expressed as working levels [WL]), and the outdoor airborne particulate concentrations were measured during November 1975 at 10 sampling locations (Figure 1) in the study area. The following report discusses only the results of the radiation surveys, radioactivity in soils, and the radon and radon progeny concentrations determinations. The results of the airborne particulate measurements are the subject of another report to be published at a later date.

Upon selection of a site as a suitable air sampling location, indoor and outdoor gamma radiation surveys were completed. This survey was done to insure that the location was not constructed upon an area of elevated terrestrial radioactivity, or that some uranium ore or other radioactive material was not present inside the structure. Such conditions could have biased the ambient outdoor radon levels and/or the indoor working level determinations.

A pressurized ionization chamber (PIC)[1] was used to measure the radiation exposure rate (ER) in units of microroentgen per hour (μR/h). The PIC is calibrated using a "shadow shield" method employing a cobalt-60 source calibrated by the National Bureau of Standards. The PIC is then inter-calibrated to respond to a radium-226 gamma spectrum. The PIC measures both the cosmic and terrestrial gamma source exposure rates. All PIC measurements were made at a height of one meter above ground surface. For the indoor measurements, the PIC determination was made in about the center of the room in which the indoor air sampler was located.

Radiation surveys were also made using a portable gamma scintillator survey meter.[2] This instrument was calibrated with a radium-226 standard and measures the relative gamma radiation exposure rate in units of μR/h. Table 1 presents the radiation exposure rates measured at each location (indoor and outdoor) for both types of detectors.

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1. Reuter Stokes, Model RSS-111 Environmental Radiation Monitor.
2. Baird-Atomic, Type NE148A - Gamma Scintillator Ratemeter.

TABLE 1. RADIATION SURVEYS

Location Code	Indoor Radiation Level (μR/h at 1 meter)		Outdoor Radiation Level (μR/h at 1 meter)		Radium-226 Content Top 5 cm Soil
	Pressurized Ionization Chamber	Scintillator Survey Meter*	Pressurized Ionization Chamber	Scintillator Survey Meter*	(pCi/g)
800	16.0	9	14.5	9	6.2
801	13.0	8	15.5	3	14.0
802	17.5	20	24.0	30	10.0
803	16.0	10	15.5	10	1.6
804	13.0	9	14.5	11	3.3
805	16.5	19	15.5	19	2.2
806	29.0	30	37.0	45	18.0
807	15.0	3	17.5	10	2.1
808	17.5	16	19.0	18	3.6
810	no survey	no survey	15.5	10	1.6**

* Gross values as measured with the field instrument.

** Top 10 cm of soil.

Since the scintillator survey meter utilizes such a small NaI crystal (1x1-1/2 inch) detector, its response is energy dependent and, therefore, measurements made using this survey meter should be "corrected" to the PIC exposure rates. This correction factor has been derived from a least squares fit of the regression line of the measurements of the PIC versus the scintillator survey meter (Table 1). Two correction expressions have bee: obtained for the indoor and the outdoor measurements as follows:

$ER = 1.1S + 2.5$ (μR/h) - Indoor Measurements

$ER = 0.9S + 3.4$ (μR/h) - Outdoor Measurements

"S" is the meter reading of the scintillator survey meter and "ER" is the corrected exposure rate based on the calibrated PIC measurements.

In general, measurements by both types of detector indicate that the indoor radiation levels are slightly lower than the outdoor levels. This is the "housing factor" effect which represents the gamma shielding characteristics of the structure for both cosmic and terrestrial sources of radiation and includes the contribution from the natural radioactivity of building materials. The radiation levels at locations #802, 806, and 808 appear to be slightly elevated compared to the other locations. Considering locations #800, 801, 805, and 807 as representative of normal background radiation conditions, the average indoor and outdoor exposure rate (PIC measurement) was about 15 and 16 μR/h, respectively. Therefore, the typical housing factor for these background locations was 0.9.

AMBIENT OUTDOOR RADON-222 CONCENTRATIONS

Sampling System and Analytical Methods

A continuous, low-volume sampling system was used to obtain the ambient outdoor radon sample (U.S. Public Health Service, 1969). This sampling technique consists of drawing filtered air through a small, low-volume air pump (less than 10 ml/min sampling rate) into a 30-liter Mylar bag. The air intake was about one meter above the ground surface. Usually a continuous 48-hour air sample was collected and analyzed for radon content.

Radon analysis was completed at a field laboratory using a portable apparatus for sample preparation (Johns, 1975). This system permits the transfer of the 48-hour ambient air sample into a container of known volume, followed by circulation through water and carbon dioxide traps. Radon is retained on two charcoal traps maintained at a temperature of about minus 80°C using dry ice and acetone. The sample is then de-emanated into a Lucas scintillation cell using helium at 400°C. The Lucas cell is held for 4-1/2 hours to allow for the ingrowth of the radon daughters and then counted on a photomultiplier tube/scaler unit.

Table 2 summarizes the ambient outdoor radon concentrations which are given in full in Tables B-1 through B-9 (Appendix B). All reported results are the measured ambient concentrations and have not been corrected for "background" radon levels.

Meteorological data obtained during this study are summarized in Appendix C.

Geologic Influences on Radon Concentrations

The determination of typical radon background concentrations for the Ambrosia Lake area is complicated by the difficulty of specifically identifying the natural versus "man-induced" radon source terms. Several geologic formations in the area average from 0.05 to 0.25 percent uranium (Kottlowski, 1975) and provide a naturally elevated radon source term. The multiplicity of "man-induced" radon source terms (e.g., mill and ion exchange plant effluent discharges, tailings ponds/piles, mine ventilation exhausts, and ore storage piles) add to the ambient radon levels in the area. The lack of adequate sampling locations due to the non-availability of electrical power also hampers a sampling scheme aimed at identifying specific radon source terms.

TABLE 2. SUMMARY OF AMBIENT OUTDOOR RADON-222 CONCENTRATIONS AND INDOOR RADON PROGENY LEVELS

November, 1975

		AMBIENT OUTDOOR RADON-222 CONCENTRATION (pCi/l)			INDOOR RADON PROGENY		PERCENT EQUILIBRIUM*
Location Code	Location Description	Maximum	Minimum	Average	Average Working Level (WL)	Sampling Time (Hours)	Percent (%)
800	Milan City Hall	2.7	0.13	1.2	0.0129	687.3	108
801	Bluewater Village	2.8	0.21	0.79	0.0045	328.1	57
802	Milan	4.9	0.46	2.2	0.0128	697.0	58
803	Broadview Acres	3.6	0.24	2.1	0.0271	628.5	129
804	Ambrosia Lake Highway Junction	3.4	0.21	1.9	0.0096	296.9	51
805	San Mateo	0.90	0.062	0.36	0.0024	620.5	67
806	Ambrosia Lake Post Office	5.4	1.0	3.1	0.0257	615.0	83
807	Bluewater	1.8	0.32	1.1	0.0077	586.1	70
808	Ambrosia Lake Trailer Park	6.6	1.3	3.6	0.0148	486.5	40
810	Thoreau	0.14	0.07	0.11	No sample		--

* Percent equilibrium equals the working level value divided by the ambient radon concentration divided by 100 pCi/l; since, one working level is equivalent to 100% equilibrium of 100 pCi/l radon and its progeny. (See discussion in text under INDOOR RADON PROGENY LEVELS.)

The sampling locations used in the study were evaluated in terms of geologic characteristics and orientation with respect to mining and/or milling activities (Table 3). This helped in assessing whether background or man-induced elevated conditions were present, and was prerequisite to realistic grouping of the radon and radium data for statistical testing. Additional background information concerning geologic conditions as related to uranium occurrence and the terrestrial radon flux are contained in Appendix A.

The data were grouped into control (background) and mining/milling area categories as shown in Table 4. Basically, the geologic settings considered consist of alluvium over barren (i.e., containing 0.1 percent or less uranium) sedimentary or basalt bedrock. The first comparison involved relatively thick sequences (>50 feet) of alluvium over barren rock whereas the second considered much thinner alluvium (<50 feet) underlain by bedrock that probably was barren but may have contained slightly elevated levels of uranium.

Statistical testing was done using the Mann-Whitney test (Mann and Whitney, 1947; Siegel, 1956) which enables comparison of two independent sample sets (using ordinal measurement) to see whether the samples are drawn from the same population. It is one of the most powerful of the nonparametric tests and is particularly useful when the inherent assumptions of the parametric tests cannot be satisfied. The power-efficiency of the Mann-Whitney test approaches 95.5 percent of the most powerful parametric test (the t test) as N, the number of observations, increases. To employ the test, the radiochemical data are put in ascending order, assigned ranks and then the latter are grouped according to whether they are from control or elevated sampling locations. The statistic U is calculated using either of the following formula:

$$U = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1$$

$$U = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2$$

Where

R_1 = sum of the ranks assigned to the group with sample size n_1

R_2 = sum of the ranks assigned to the group with sample size n_2

Depending on the values of n_1 and n_2, either critical values of U or probabilities associated with the observed U are used to

TABLE 3. SUMMARY OF RADON AND RADIUM ANALYTICAL RESULTS AND GEOLOGIC CHARACTERISTICS FOR SAMPLING LOCATIONS

Sampling Location#	Location	Average Radon Concentration In Air pCi/l	Radium In Soil (Top 5 cm) pCi/g	Geologic Conditions: Substrate	Geologic Conditions: Estimated Thickness (feet)	Geologic Conditions: Underlain By	Remarks
800	Milan	1.2	6.2	Alluvium	125	Interbedded basalt flows & Chinle Fm.	Background; geologic conditions broadly similar to stations 801, 802, 803, 807
801	Bluewater	0.79	14	Alluvium	90	San Andres Limestone	Background; geologic conditions broadly similar to stations 800, 802, 803, 807
802	UNHP mill area (0.3 mi E of mill)	2.2	18	Alluvium	50-75	Chinle Formation	Elevated radon due to milling?
803	UNHP mill area (1.0 mi SSW of mill)	2.1	1.6	Alluvium	50-75	Chinle Formation	Elevated radon due to milling?
804	Ambrosia Lake (Junction of NM 53 and 509)	1.9	3.3	Alluvium	30	Westwater Canyon Member	Possibly naturally high radon
805	San Mateo	0.36	2.2	Alluvium	30	Point Lookout Sandstone & Menefee Formation	Background; geologic conditions similar to stations 806, 807, 808; no tailings; closest mine ventilation 3 miles NW; minimal shaft ventilation locally
806	Ambrosia Lake (1.3 mi NE of Kerr-McGee mill)	3.1	18	Alluvium	40	Mancos Shale	Elevated radon due to mining, milling? Mine ventilation exhaust nearby.
807	Anaconda Co. mill area (1.6 mi SE of mill)	1.1	2.1	Basalt Flow	50	Alluvium	Elevated radon due to milling?
808	Ambrosia Lake (1.1 mi ENE of Kerr-McGee mill)	3.6	3.6	Alluvium	30	Mancos Shale	Elevated radon due to mining, milling? Mine ventilation exhaust nearby.
810	Thoreau area (7.3 mi NE of Thoreau)	0.11	1.6*	Alluvium	10-50	Dakota Sandstone Mancos Shale	Background; geologic conditions similar to stations 806, 808; no mine ventilation or tailings in area.

* Top 10 cm

TABLE 4. COMPARISON OF AVERAGE RADIUM AND RADON DATA

Geologic Setting	Control (Background) Radium (pCi/l)	Control (Background) Radon (pCi/l)	Locations Considered		Elevated (Mining/Milling Areas) Radium (pCi/l)	Elevated (Mining/Milling Areas) Radon (pCi/l)
Thick alluvium or basalt/ underlain by barren rock	6.2	1.2	800			
				802	18	2.2
	14.0	0.79	801			
				803	1.6	2.1
	2.1	1.1	807			
Thin alluvium/ underlain by barren (?) rock				804	3.3	1.9
	2.2	0.36	805			
				806	18.0	3.1
	1.6	0.11	810			
				808	3.6	3.6

accept or reject the null hypothesis at the preset level for alpha, usually 0.05 or 0.01.

Radon concentrations in background locations and in the areas of active mining and milling were considered using 125 individual field measurements of ambient air quality (Tables B-1 through B-9) and averages of these data (Table 4). In both cases the data were separated into control (background) and elevated categories according to the breakdown in Table 4 and on the basis of the information shown in Table 3.

Using the averaged radon data for the five control stations (#800, 801, 805, 807, 810) and five stations in areas of active mining and milling (#802, 803, 804, 806, 808), a two-tailed test at the five percent level of significance indicates significant difference in ambient radon concentrations between sampling points. When actual individual data versus averaged values are compared, the degrees of freedom (number of observations minus one) increase from 9 to 124 and thereby increases the strength of the test. In this instance, and again using a two-tailed test, there is a statistically significant difference in radon concentrations between the two types of sampling points at the one percent level of significance. In short, ambient radon in air is significantly greater in areas of active mining and milling than in areas considered to be background.

Results

At San Mateo (Location #805), ambient outdoor radon concentrations ranged from 0.06 to 0.90 pCi/l (Table B-6). The average concentration was 0.36 pCi/l, with a standard deviation of 0.21 pCi/l. These results are comparable to radon levels measured at three locations in the vicinity of San Mateo during sampling periods extending from September 1972 to August 1973 (New Mexico Environmental Institute, 1974). Measured at three feet above ground surface, radon concentrations ranged from 0.008 to 0.91 pCi/l, with an overall mean of 0.19 pCi/l for the eight-month sampling program. The statistical error in counting and sampling has a standard deviation of ±12 percent (i.e., 0.19 ± 0.04 pCi/l, at the 95 percent confidence level).

The village of San Mateo is underlain by the Point Lookout Sandstone and Menefee Formation, neither of which is ore bearing. Beneath these are the Gallup Sandstone and Crevasse Canyon Formations. All four units probably contain 0.05 percent or less uranium. During the November 1975 study, ventilation of the nearby mine shaft may have slightly elevated the ambient radon levels. However, since the shaft was only advanced to a depth of 500 feet, and the target ore body is at a depth of 3,000 to 4,000 feet, significant radon from a single vertical shaft without any lateral drifts is believed to be minimal. The monthly average ambient radon concentration of 0.36 ± 0.42 pCi/l for this study is about twice the previously reported determinations made prior to shaft sinking and extending over a longer time period (i.e., mean of 0.19 pCi/l for the 1974 report). Both results are believed to be representative of local background radon levels prior to extensive mining or uranium mill operations, but the increase in 1975 relative to 1974 suggests that additional data are necessary to adequately define annual variations.

During November 1975, the monthly average ambient radon concentration at location #801 in Bluewater Village was 0.79 ± 1.2 pCi/l (Table B-2). Geologic conditions at this site consist of several hundred feet of saturated alluvium underlain by carbonate and clastic bedrock essentially devoid of uranium; i.e., less than 0.05 percent uranium. In addition, Bluewater Village is about two miles upwind of the Anaconda Company mill and associated tailings pond; therefore, the measured radon levels at this location are believed to be representative of local natural background conditions.

Location #807, a private residence about 1.6 miles southeast of the Anaconda Company mill, is located in an area characterized by very thin alluvium underlain by a basalt flow (bedrock). The monthly average radon level was 1.1 ± 1.0 pCi/l (Table B-8).

Although Thoreau (Location #810) is at the mouth of a valley similar to the Ambrosia Lake Valley, the sampling location was topographically and stratigraphically below exposures of the Westwater Canyon Member of the Morrison Formation, the principal ore-bearing unit in the Grants Mineral Belt. Therefore, the average radon content (0.11 pCi/l) is probably less than the background radon level in the Ambrosia Lake area.

Until additional studies are completed to better define radon background conditions in the Ambrosia Lake area, the best estimate of background radon concentrations may be obtained by considering locations #800, 801, 805, 807, and 810. These five locations are somewhat removed (at least one mile distant) from the immediate vicinity of any uranium mill or active mining operation, and are not in close vertical or lateral proximity to the uranium-bearing formations. In November 1975, the mean radon concentration for these five "background" locations was 0.72 pCi/l, with a standard error of 0.21 pCi/l.

Two sampling locations (#802 and 803) were established in the vicinity of the United Nuclear-Homestake Partners (UNHP) mill and tailings pond complex. Location #802 is within 200 yards and directly east of the UNHP complex and had a monthly average radon concentration of 2.2 pCi/l (Table B-3). Location #803 (Table B-4) is about one mile south-southwest of UNHP and averaged 2.1 pCi/l radon for November 1975. The area surrounding the UNHP complex is underlain by approximately 100 feet of alluvium (half of which is saturated) which overlies the Chinle Formation. Neither unit is considered ore bearing at any location in the Grants Mineral Belt because of the low uranium content (probably below 0.05 percent). Radon diffusion is also expected to be minimal due to the overlying, near-surface ground water which inhibits radon diffusion. The average monthly radon levels of 2.1 and 2.2 pCi/l for the two sampling locations in the vicinity of the UNHP complex appear to be in excess of natural background concentrations and indicate that the active mill complex is apparently the source of elevated radon concentrations.

Location #804 is at the junction of State highways 509 and 53, about five miles east-southeast of the Kerr-McGee mill in the Ambrosia Lake area. Although this location is downwind from the mines and mills, the elevated radon level of 1.9 pCi/l (Table B-5) may be influenced by nearby outcrops of the Westwater Canyon Member, the principal ore-bearing unit in the Ambrosia Lake area. This station was regarded as elevated despite the distance from active mines and mills. (For purposes of statistical comparison of "background" versus "elevated" conditions, this decision is conservative in that the radon and radium concentrations for this location are slightly lower than the other elevated locations.)

The highest radon concentrations in ambient air were measured in the Ambrosia Lake area where there is an active mill, numerous active mines, and an inactive mill and associated tailings pile. For location #806, the highest radon level was 5.4 pCi/l (Table B-7), with an average of 3.1 pCi/l for November 1975. The highest radon concentration measured at any of the sampling locations was 6.6 pCi/l, with a monthly average of 3.6 pCi/l (Table B-9) at location #808. Both locations are nearby mine ventilation exhaust ducts and these results indicate that elevated radon levels also occur in the vicinity of the active uranium mining and milling operations in the Ambrosia Lake area.

RADIUM IN SOIL

Soil samples were also collected at each air sampling location. The results of analyses for radium-226 content are reported in Table 1. Each soil sample was obtained at the same spot as were the outdoor radiation measurements. A standardized sampling procedure, which utilized a steel scoop, 5-cm deep and 100-cm² in surface area, was established to obtain a standard soil sample of 500 cm³, representing activity in the top five centimeters of soil. The highest concentration of radium-226 in soil (18 pCi/g) was at locations #806 and 802, both of which are in close proximity to active uranium milling operations. These elevated radium levels probably represent windblown tailings or ore dust in addition to the naturally occurring terrestrial levels measured at the other sampling locations. The unusually high radium-226 content of 14 pCi/g at location #801 is difficult to explain, but may be due to a natural terrestrial anomaly. Radiation levels at location #801 do not appear to be elevated compared to the levels measured at the other two locations with the higher radium in soil contents. Further discussion of the uranium content of soil and rock materials in the study area is contained in Appendix A.

The Mann-Whitney test was also used to compare the radium in soil data as shown in Table 4. Although the average radium content in the mining and milling areas is 8.9 pCi/g versus 5.2 pCi/g in the background samples, the difference is not significant at the five percent level of significance. Despite the limited data, this suggests that radium in local soils is probably not the principal influence on elevated airborne radon concentrations and that other mining/milling-related factors are of greater importance.

Radium concentrations in the upper five centimeters of soil (Table 4) average 8.9 pCi/g at five locations (#802, 803, 804, 806, 808), all of which are within 0.3 to 2 miles (average 1.2 miles) of active uranium mills and associated tailings. Elevated levels relative to background locations may be a result of windblown tailings, although it is unlikely that the high radium (14 pCi/g) in soil at Bluewater (Location #801) can be attributed to the nearby Anaconda Company mill because the prevailing wind direction is from the north to northwest. The alluvium in the Bluewater area is expected to be low in radium, i.e., 1 to 3 pCi/g or less. At location #807, which is 1.6 miles southeast and therefore downwind of the Anaconda Mill site, radium is only 2.1 pCi/g, or essentially equal to that in the background samples from Thoreau (Location #810, 1.6 pCi/g) or San Mateo (Location #805, 2.2 pCi/g).

Radium concentrations in the vicinity of the UNHP mill range from 1.6 to 18 pCi/g. Although the prevailing winds are from the north to northwest, windblown tailings have been observed in the trailer court 0.3 miles east of the mill (Location #802). This could account for the elevated levels (18 pCi/g) compared to location #803 which is downwind, but a mile away and possibly not representative in that the soil sample was taken from a corral area where fine materials may have been scattered by stock. Similarly, distance and soil reworking may account for the relatively low value of 2.1 pCi/g at location #807 which was an actively plowed and irrigated field 1.6 miles southeast of the Anaconda Company mill.

In Ambrosia Lake, radium content of surficial soils is also highly variable, ranging from 3.3 to 18 pCi/g. The highest concentration is 1.3 miles northeast of the Kerr-McGee mill.

Therefore, it appears that radium concentrations in surficial soils adjacent to active mining and milling operations do not readily correlate with known sources of radium and available wind data. Local weather conditions, particularly wind speed and direction, winnowing or mixing processes associated with human activities, and influences from other local sources such as ore trucks and other heavy equipment associated with mining/milling may contribute to the observed high degree of variability. It is clear though that background locations (#800, 805, 810) are uniformly low (average radium = 3.3 pCi/g), as compared to those locations near active mills e.g., #802, 806, and 808 (average radium = 13.2 pCi/g).

Discussion

In summary, examination of the radon data indicates that radon concentrations in air in the Ambrosia Lake area and in the vicinity of the Anaconda Company and UNHP mills are statistically elevated relative to locations in Bluewater, San Mateo, and Milan. Identification of specific source terms (i.e., natural versus man-induced) cannot be resolved with data from the present study. Although elevated radon concentratons may be attributable to the relative abundance of uranium-bearing bedrock in the Ambrosia Lake area, the radium in soil data suggest that the principal influences are man-induced radon originating in the tailings piles, mill and mine exhausts, or ore stockpiles.

Current Federal and State of New Mexico regulations for the nuclear industry are shown in Table 5. Insofar as these regulations permit annual averaging of concentrations for compliance monitoring purposes, and considering the fact that all samples were collected in unrestricted areas occupied by the general population, it is reasonable to apply the population guide of one-third the 168-hour value (i.e., 1 pCi/l radon) for radon sources covered in the regulations. The dose equivalent from the continuous exposure to the regulatory limit of 3 pCi/l for radon (under equilibrium conditions similar to those of living accommodations with normal ventilation) is estimated to be 12 rem per year to the lung (Swift et al., 1976). Therefore, unless there is appreciable seasonal variations in radon levels, significant exposures of populations in active mining and milling areas such as the Ambrosia Lake area may be occurring. Additional studies to evaluate all exposure routes and any seasonal variations in radon levels in the Ambrosia Lake area are suggested.

TABLE 5. EXPOSURE LIMITS FOR RADON-222 AND RADON PROGENY*

Regulation Source	40 hour Exposure Limits (Restricted Area Annual Average)	168 hour Exposure Limits (Unrestricted Area Annual Average)**
Nuclear Regulatory Commission (10CFR Part 20) January 29, 1976 Appendix B	30 pCi/l (0.33 Working Levels)	3 pCi/l (0.03 Working Levels)
New Mexico Environmental Improvement Agency Regulations for Governing the Health and Environmental Aspects of Radiation June 16, 1973, Part 4 Appendix A	100 pCi/l	3 pCi/l

* Concentrations Above Natural Background.

** Population exposure in unrestricted area may be limited to one-third Table II values per NRC 10CFR20, Section 20.106 (e) and/or NMEIA-Part 4-160, para. E.

Several other situations exist which should be evaluated with respect to minimizing radiation exposure risks to populations in mining/milling areas. A mine ventilation exhaust duct typical of those scattered throughout the Ambrosia Lake area is shown in Figure 2. Perhaps a vertical exhaust discharge arrangement, as opposed to the horizontal discharge shown in Figure 2, would provide additional dilution of exhaust gases containing elevated concentrations of radon and radon progeny. In order to minimize population exposures, a populated zone restriction should be considered for active mining areas and engineering planning could also be formulated to locate mine exhaust ducts in areas which would not affect the air quality of existing populated areas.

Due to the extensive development of underground mining in the Ambrosia Lake area, land surface subsidence has occurred in several areas. The use of mine overburden or uranium ore materials as landfill in such areas, as shown in Figure 3, provides another source term for increasing radon levels. It is suggested that appropriate radiological surveys be conducted to assure public health and safety prior to any use of mine overburden, mine ore, or tailings material in reclaiming land; particularly if the land is to be used for construction of housing or other structures.

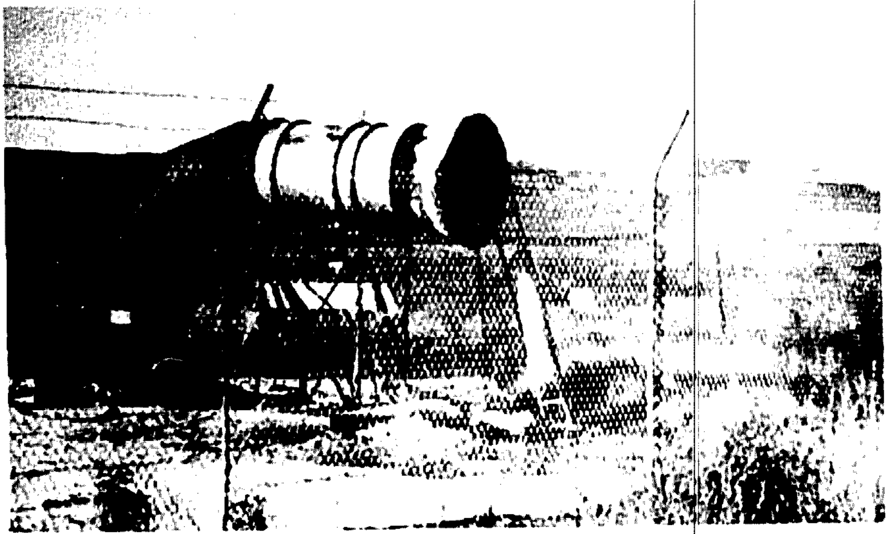

FIGURE 2. TYPICAL MINE VENTILATION EXHAUST DUCT

FIGURE 3. MINE OVERBURDEN OR ORE MATERIALS USED AS LANDFILL

INDOOR RADON PROGENY LEVELS

Sampling System and Analytical Methods

The indoor radon progeny levels were measured using a Type II, TLD-Radon Progeny Integrating Sampling Unit (RPISU) (Schiager, 1971). This sampling unit uses thermoluminescent dosimeter disks (TLD) to absorb the alpha particle emissions from the radon progeny collected on a membrane filter through which the sampled air has passed.

The measurement of stored energy in the exposed TLD disk is obtained with a Harshaw Model 2000-TLD reader. The reader gives a readout in nanocoulombs which is converted to a working level (WL) value by utilizing a working level-liter per nanocoulomb (WL-l/nC) conversion factor which is obtained through calibration tests in known radon progeny atmospheres. All WL determinations were completed at the Las Vegas facility of ORP.

Results and Discussion

The average ambient indoor radon progeny levels for November 1975 are presented in Table 2 and shown in Figure 1. All sample results (i.e., ambient values uncorrected for background level) for each sampling location are contained in Tables D-1 through D-9, Appendix D.

Current Nuclear Regulatory Commission regulations (January, 1976) limit radon progeny levels to 0.03 working levels (above natural background) for continuous exposure in unrestricted areas (Table 5). Another guideline for continuous exposure to indoor radon progeny concentrations was established by the U.S. Surgeon General in 1970. These guides were promulgated as a result of the health hazard evaluation of the use of uranium mill tailings material for construction purposes. These guides provide remedial action recommendations for three ranges of working level values above natural background. In summary, for locations with WL values less than 0.01 WL, no remedial action is recommended. For sites exceeding 0.05 WL, remedial action to reduce WL exposure is indicated. For the range 0.01 to 0.05 WL, the need for any remedial action may be suggested after due consideration of all exposure routes and cost estimates of remedial action alternatives. These Surgeon General Guidelines have effectively been applied to the Grand Junction, Colorado remedial action program for structures incorporating tailings material. The natural background WL value for the Grand Junction area was determined to be 0.004 WL (Joint Committee on Atomic Energy, 1971).

During this study, sampling difficulties were encountered at several indoor locations (e.g., #801 and 804) which had wood or coal burning fireplaces, cigarette smokers, or excessive dust created by nearby vehicular traffic. Such atmospheres were characterized by excessive airborne particulate matter which caused the TLD air sampler to shut off due to excessive dust loading of the membrane filter. Because of this, minimum sample volumes were obtained for locations #801 and 804 (Tables D-2 and D-5, respectively); hence, there may be large error terms in these reported determinations.

Considering locations #800, 801, 805, and 807 as representative of "background" locations, the mean working level determinations was 0.0069 WL, with a standard error of 0.0046 WL. These indoor radon progeny working level determinations are consistent with the outdoor ambient radon concentration results (Table 1). Both evaluations show the same trend of elevated levels in the vicinity of uranium mills or active mining operations, as in the Ambrosia Lake area.

Assuming that the indoor radon concentration would be equal to the measured ambient outdoor concentration, the percent equilibrium of radon and its progeny may be calculated. These results are shown in Table 1. The calculated percentage equilibrium for locations #800 and 803 exceed 100 percent and signifies that it is erroneous to assume that the indoor radon level is equal to the measured outdoor concentration for these two locations. That is, for locations #800 and 803, the indoor radon levels are probably in excess of 1.2 and 2.1 pCi/l, respectively. The percent equilibrium for all other sampling locations ranges from 41 percent to 83 percent, with an average equilibrium percentage of 61 percent. Such high equilibrium values are indicative of the low air exchange rates for the season (i.e., wintertime when doors and windows are not open), and the type of passive heating systems of the structures (i.e., wood or coal burning fireplaces rather than forced air heating systems with filtration).

An initial screening survey, during the week of June 11-17, 1974, measured the indoor radon progeny working levels in two private residences directly east of the UNHP mill site. One location had 0.0282 WL for the 144.1-hour sampling period. The second location (#802) had a value of 0.0106 WL for the 144.9-hour sampling period. For the November 1975 study, the average ambient radon progeny working level for location #802 was 0.0128 WL (Table D-3). Although the November value is slightly higher than the June level at location #802, no definite conclusion can be made regarding seasonal variations of radon progeny. Therefore, it is recommended that additional long-term evaluations of the indoor radon progeny working level be undertaken for selected locations in the vicinity of mining and milling operations.

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APPENDIX A

GEOLOGIC FACTORS AFFECTING ATMOSPHERIC RADON

The Grants Mining District, which includes the Ambrosia Lake area, is one of three active districts in the Grants Mineral Belt. Other districts of importance are located north of Laguna, about 27 miles to the east, and Churchrock, located 33 miles west-northwest. Relatively inactive districts are located about 19-24 miles west in the Mariano Lake-Smith Lake areas, although there has been no significant production to date.

Geologic conditions in the Grants Mineral Belt, particularly as they relate to the occurrence of uranium deposits, are summarized in reports by Trauger (1967) and the New Mexico Bureau of Mines and Mineral Resources (1963). The Grants Mineral Belt is flanked on the north and northeast sides by the San Juan Basin, on the east by the Rio Grande trough, and on the south and west by the Acoma sag and the Zuni uplift. Exposed sedimentary rocks in the area range in age from Pennsylvanian to Cretaceous and rest on Precambrian gneiss, schist, and granite exposed in the core of the Zuni uplift. Intrusive and extrusive rocks of the Mount Taylor and Zuni volcanic fields are of Tertiary and Quaternary ages. The regional dip of the sedimentary rocks is northward to northeastward, the latter direction prevailing in the Ambrosia Lake-Grants mining district. Areally, the most extensive units in the Grants District consist of limestone, shale, sandstone, and basalt flows (see Figure A-1).

Differential erosion has creat^d a series of northwest-trending escarpments generally capped by thick-to-massively-bedded sandstone and underlain by less resistant shale and thin-bedded sandstone. In the area surrounding Grants-Bluewater and Ambrosia Lake, mesas are formed where erosional remnants of the escarpments are covered by lava which is extremely resistant to weathering. Extensive basalt flows of Tertiary and Quaternary age originated in the Zuni Mountains to the south, in Mount Taylor to the east, and in a volcanic cone known as El Tintero (the inkwell) located five miles north-northeast of Bluewater. Not shown in Figure A-1 is the alluvium which floors the principal valleys and is thickest (average 100-300 feet) in Bluewater Valley extending from Bluewater to Grants. The alluvium is absent on the crests and steep sides of the mesas and escarpments. A relatively thin covering (average = 40 feet or less) is believed present in the central portions of the Ambrosia Lake area and at the toe of steep slopes forming the northern and eastern boundaries.

LEGEND

GEOLOGIC UNITS

AGE	MAP SYMBOL	UNIT
QUATERNARY, TERTIARY	Qal	ALLUVIUM
	QTv	VOLCANIC ROCKS, UNDIFFERENTIATED
CRETACEOUS	Kpm	POINT LOOKOUT SANDSTONE & MENEFEE FORMATION
	Kgc	GALLUP SANDSTONE & CREVASSE CANYON FORMATION
	Kdm	DAKOTA SANDSTONE & LOWER MANCOS SHALE
JURASSIC	Jm	MORRISON FORMATION—WESTWATER CANYON MEMBER
	J	JURASSIC STRATA BENEATH MORRISON FORMATION
TRIASSIC	Ꞧ	CHINLE FORMATION & WINGATE SANDSTONE
PERMIAN	P	PERMIAN STRATA, UNDIFFERENTIATED
PRECAMBRIAN	pE	PRECAMBRIAN ROCKS, UNDIFFERENTIATED

MISCELLANEOUS

	GEOLOGIC UNIT CONTACT
▲	SHAFTS
■	URANIUM MINE
	URANIUM MILL
□	SETTLEMENTS/TOWNS
	URANIUM MINERALIZATION AT OR NEAR LAND SURFACE
● B02	AIR SAMPLING STATION

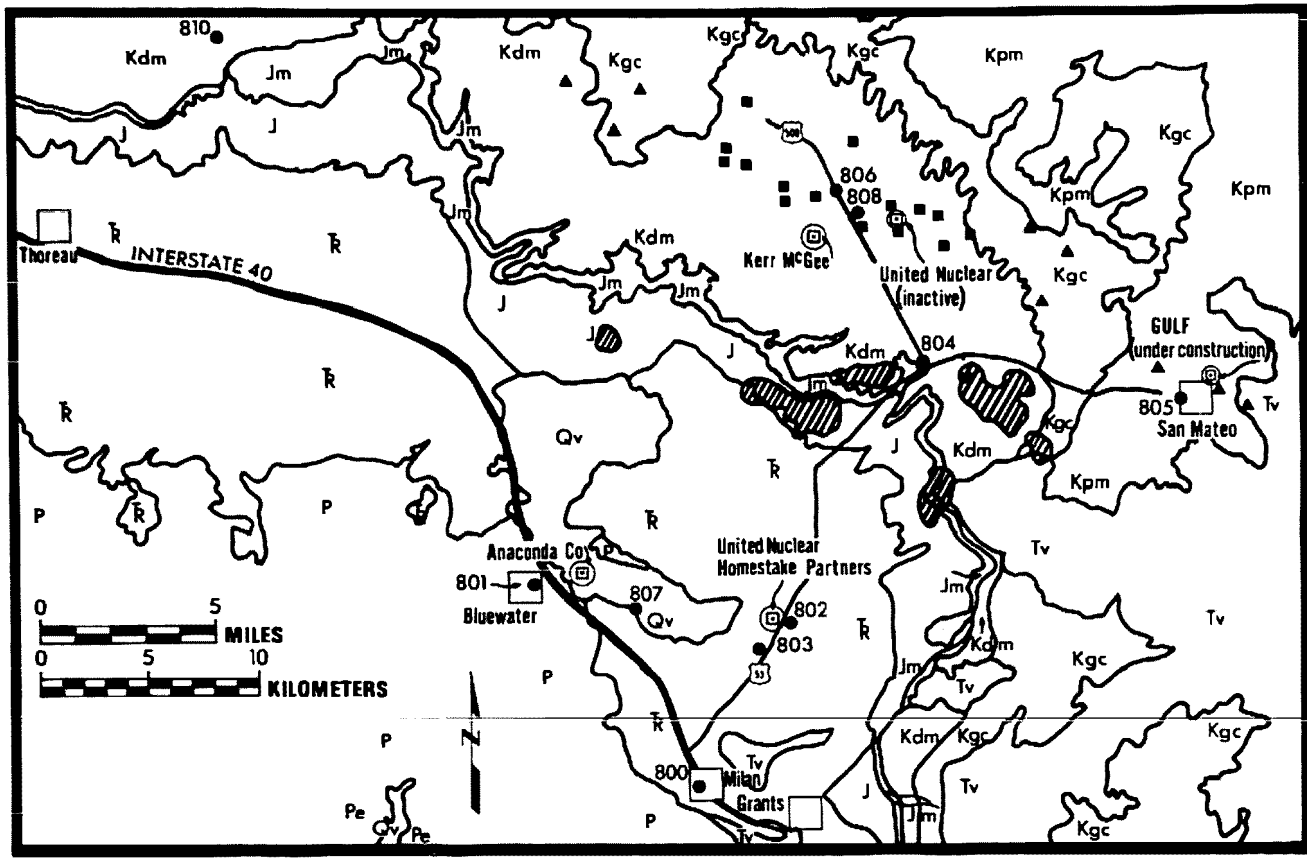

FIGURE A-1. GEOLOGIC MAP OF THE AMBROSIA LAKE MINING DISTRICT AND VICINITY
(Adapted from Chapman, Wood, and Griswold, Inc. 1974)

URANIUM OCCURRENCE

Several uranium-bearing formations crop out in the Grants Mineral Belt region along the east-west trending escarpments and on the flanks of major north-south trending valleys incised into the escarpments by ephemeral streams. At depths of 700 to 4,000 feet, the uranium content of the Morrison Formation locally averages 0.25 percent and is therefore of commercial value. At the surface or outcrop, this formation averages about 0.1 percent uranium whereas other bedrock formations usually contain less than 0.05 percent uranium.

Uranium mineralization in the Grants Mineral Belt varies greatly depending on the particular geologic unit(s) considered, the depth of burial, and subtle but highly selective natural enrichment processes. The latter involve multiple weathering cycles, regional uplift and erosion, unique paleohydrological conditions and geochemical factors, chief of which are entrapped organic substances in the clastic sediments and chemically reducing conditions. For all practical purposes, marked occurrence of ore, i.e., rock having a minimum average uranium content of 0.25 percent, is limited to the Westwater Canyon Member of the Morrison Formation. Furthermore, ore in this unit generally occurs at depths of several hundred feet or more and is probably related to a reducing environment associated with the occurrence of the regional ground-water table. Closer to the outcrop of the Westwater Canyon Member, oxidizing conditions and active leaching processes have largely removed any uranium that may have been present. Exceptions to this rule are found in shallow uranium deposits in the Poison Canyon area, immediately south of Ambrosia Lake, which are associated with the Entrada Sandstone or limestones of the Todilto Formation. Similar deposits in Haystack Butte were the basis for the first ore discovery in the region in the early 1950's. Oxidizing conditions and leaching, plus the fact that many of the source rocks contain average or below average uranium concentrations, result in depleted levels of uranium in alluvial sediments relative to sedimentary bedrock.

Uranium ore has been produced from various units including the Entrada Sandstone, Todilto Limestone, Summerville Formation, Bluff Sandstone, Morrision Formation, and the Dakota Sandstone. The aggregate thickness of the ore-bearing units is 1,000 to 1,500 feet. The Morrision Formation has yielded about 94 percent of the ore and probably contains over 95 percent of the reserves (Kittel et al., 1967).

Sedimentary bedrock units containing low to intermediate concentrations of uranium include the Cretaceous strata (Gallup Sandstone, Crevasse Canyon Formation, Mancos Shale, Point Lookout Sandstone, Menefee Formation), and the Jurassic Morrison Formation (exclusive of the Westwater Canyon Member). Studies of uranium content in the Dakota Sandstone, Mancos Shale, and Point Lookout Sandstone exposed in the La Ventana area some 65 miles east of Ambrosia Lake were made by Bachman et al. (1959). They observed beds of coal, carbonaceous shale, and carbonaceous sandstone containing a maximum of 0.62 percent uranium. The average content in the "high grade" zones was 0.1 percent and much larger areas contained between 0.01 and 0.10 percent. Although conditions may be different in the Ambrosia Lake area, these analytical results give some credence to the 0.01 percent level selected for uranium in nonmineralized strata.

Uranium concentrations in 10 samples of carbonaceous shale collected in the summer of 1975 from the La Ventana mesa area averaged 0.69 pCi/g uranium and from 0.79 to 4.2 pCi/g of radium-226. This is essentially background for any area and is evidence that at least the Menefee Formation is not a significant source of abnormal amounts of radon. This may also be true of the remaining Cretaceous strata beneath the Menefee.

Units of Pennsylvanian through Triassic age are probably of average or below average uranium content relative to the average for crustal rocks. These units include the Abo, Yeso, Glorieta, and San Andres formations which are present south of and beneath Bluewater Valley. The Chinle Formation (Triassic) which is also believed to be in this category, is exposed from just north of the Anaconda Company mill to the base of the escarpment forming the southwestern rim of the depression containing the Ambrosia Lake mining district (see Figure A-1). The basaltic lava flows present in the Bluewater, Milan, and San Mateo areas are also believed to be low in uranium content. Rogers and Adams (1957) and Ahrens et al., eds. (1959) report that the uranium content of basic extrusive rocks (basalts and andesites) is on the order of 0.2 to 0.4 ppm (0.00002 to 0.00004 percent) and rather evenly distributed among the various constituents. Initial estimates of radon release from formations in the Ambrosia Lake area indicated that natural sources could possibly account for the radon concentrations observed during this study. However, there are numerous assumptions in these calculations including diffusion rates, exposed surface areas for the various geologic units, and the influences of dilution (mixing) in ambient air. Differences in radon concentration among the various air sampling stations, some of which can be regarded as controls (background), suggest that local variations in geologic and other natural factors are of secondary importance compared to the influences from mining and milling operations.

In addition to the uranium content of soil/rock (and assuming radium is present in equilibrium concentrations), ground-water and soil moisture conditions significantly influence the diffusion rate for radon. The study area has a semi-arid climate characterized by about 10 inches of annual precipitation, and, except for a relatively small part of the area east of Grants, ground water is at least 50 feet below the land surface. Therefore, radium content of the soils and soil moisture are believed to be the principal factors affecting the diffusion of radon from purely natural sources.

APPENDIX B

TABLE B-1.
AMBIENT OUTDOOR RADON-222 CONCENTRATIONS
LOCATION #800-MILAN CITY HALL

On Date Time	Off Date Time	Radon-222 pCi/l	Two Sigma Error Term pCi/l
11/4/75 1000	11/5/75 0830	2.7	0.15
11/5/75 0900	11/6/75 1555	2.3	0.13
11/6/75 1555	11/8/75 0730	1.8	0.11
11/8/75 0730	11/10/75 0725	0.99	0.08
11/10/75 0730	11/12/75 0735	0.48	0.06
11/12/75 0738	11/14/75 0733	1.1	0.10
11/14/75 0733	11/16/75 0718	2.3	0.13
11/16/75 0719	11/18/75 0730	1.6	0.11
11/18/75 0730	11/20/75 0742	0.40	0.06
11/20/75 0745	11/22/75 0900	0.52	0.06
11/22/75 0800	11/24/75 0728	1.2	0.10
11/24/75 0728	11/26/75 0850	0.32	0.05
11/26/75 0855	11/28/75 0730	0.14	0.03
11/28/75 0735	11/30/75 0855	0.13	0.04
11/30/75 0900	12/2/75 0830	2.1	0.13
<u>Summary</u>			
11/4/75	12/2/75	1.2 (15 Samples)	1.7

TABLE B-2.
AMBIENT OUTDOOR RADON-222 CONCENTRATIONS
LOCATION #801-BLUEWATER VILLAGE

On Date Time	Off Date Time	Radon-222 pCi/l	Two Sigma Error Term pCi/l
11/4/75 1125	11/5/75 0750	2.8	1.1
11/5/75 0800	11/7/75 1040	0.83	0.081
11/7/75 1045	11/9/75 1108	0.55	0.074
11/9/75 1109	11/12/75 1630	0.52	0.067
11/13/75 0955	11/15/75 1000	0.90	0.085
11/15/75 1002	11/17/75 1025	1.1	0.092
11/17/75 1025	11/19/75 1038	0.54	0.067
11/19/75 1040	11/21/75 1035	0.63	0.067
11/21/75 1035	11/23/75 0932	0.85	0.081
11/23/75 0931	11/25/75 1030	0.79	0.078
11/25/75 1035	11/27/75 0935	0.25	0.042
11/27/75 0940	11/29/75 1205	0.21	0.042
11/29/75 1210	12/1/75 1205	0.48	0.063
12/1/75 1210	12/2/75 1505	0.63	0.069
<u>Summary</u>			
11/4/75	12/2/75	0.79 (14 Samples)	1.2

TABLE B-3.
AMBIENT OUTDOOR RADON-222 CONCENTRATIONS
LOCATION #802-MILAN

On Date Time	Off Date Time	Radon-222 pCi/l	Two Sigma Error Term pCi/l
11/4/75 1455	11/6/75 1130	4.9	0.18
11/6/75 1130	11/8/75 0750	2.4	0.14
11/8/75 0800	11/10/75 0750	2.1	0.12
11/10/75 0755	11/11/75 1437	0.75	0.077
11/11/75 1440	11/13/75 1509	1.4	0.11
11/13/75 1510	11/15/75 1353	3.5	0.16
11/15/75 1353	11/17/75 0805	3.9	0.17
11/17/75 0807	11/19/75 0837	1.2	0.096
11/19/75 0837	11/21/75 0830	1.6	0.11
11/21/75 0830	11/23/75 0805	4.3	0.18
11/23/75 0805	11/25/75 0832	1.1	0.087
11/25/75 0833	11/27/75 0750	0.52	0.065
11/27/75 0755	11/29/75 0945	0.46	0.057
11/29/75 0950	12/1/75 0928	1.5	0.11
12/1/75 0930	12/3/75 0740	2.6	0.13
<u>Summary</u>			
11/4/75	12/3/75	2.2 (15 Samples)	2.8

TABLE B-4.
AMBIENT OUTDOOR RADON-222 CONCENTRATIONS
LOCATION #803-BROADVIEW ACRES

On Date Time	Off Date Time	Radon-222 pCi/l	Two Sigma Error Term pCi/l
11/5/75 0955	11/7/75 0755	2.9	0.15
11/7/75 0755	11/8/75 0735	3.3	0.16
11/8/75 0745	11/10/75 0740	2.3	0.12
11/10/75 0745	11/12/75 0753	0.80	0.075
11/12/75 0755	11/14/75 0745	2.5	0.14
11/14/75 0745	11/16/75 0730	2.7	0.15
11/16/75 0730	11/18/75 0823	3.4	0.16
11/18/75 0828	11/20/75 0753	1.5	0.099
11/20/75 0755	11/22/75 0810	1.6	0.11
11/22/75 0810	11/24/75 0815	2.6	0.13
11/24/75 0820	11/26/75 0803	1.2	0.089
11/26/75 0805	11/28/75 0745	0.24	0.046
11/28/75 0750	11/30/75 0915	0.65	0.072
11/30/75 0920	12/2/75 0850	3.6	0.16
<u>Summary</u>			
11/5/75	12/2,75	2.1 (14 Samples)	2.2

TABLE B-5.
AMBIENT OUTDOOR RADON-222 CONCENTRATIONS
LOCATION #804-AMBROSIA LAKE HIGHWAY JUNCTION

On Date Time	Off Date Time	Radon-222 pCi/l	Two Sigma Error Term pCi/l
11/5/75 1140	11/7/75 0820	3.4	0.15
11/7/75 0825	11/9/75 0900	1.2	0.099
11/10/75 0812	11/12/75 0825	0.63	0.074
11/12/75 0830	11/14/75 0808	2.1	0.12
11/14/75 0808	11/16/75 0755	3.4	0.16
11/16/75 0756	11/19/75 0852	1.2	0.090
11/19/75 0854	11/21/75 0845	2.4	0.14
11/21/75 0845	11/23/75 0820	3.2	0.15
11/23/75 0823	11/25/75 0850	1.3	0.10
11/25/75 0850	11/27/75 0800	0.48	0.064
11/27/75 0805	11/29/75 1010	0.21	0.042
11/29/75 1015	12/1/75 0940	1.9	0.12
12/1/75 0945	12/3/75 0800	2.8	0.14
Summary 11/5/75	12/3/75	1.9 (13 Samples)	2.2

TABLE B-6.
AMBIENT OUTDOOR RADON-222 CONCENTRATIONS
LOCATION #805-SAN MATEO

On Date Time	Off Date Time	Radon-222 pCi/l	Two Sigma Error Term pCi/l
11/6/75 1630	11/8/75 0900	0.35	0.052
11/9/75 0935	11/10/75 1614	0.60	0.066
11/10/75 1615	11/12/75 1540	0.13	0.030
11/12/75 1536	11/13/75 1615	0.90	0.083
11/13/75 1616	11/15/75 1428	0.29	0.048
11/15/75 1430	11/17/75 0938	0.35	0.055
11/17/75 0940	11/19/75 0956	0.19	0.040
11/19/75 0958	11/21/75 0955	0.49	0.057
11/21/75 0955	11/23/75 0848	0.30	0.050
11/23/75 0850	11/25/75 0950	0.31	0.047
11/27/75 0955	11/29/75 1115	0.062	0.025
11/29/75 1120	12/1/75 1100	0.31	0.048
12/1/75 1110	12/2/75 1353	0.38	0.054
Summary 11/6/75	12/2/75	0.36 (13 Samples)	0.42

TABLE B-7.
AMBIENT OUTDOOR RADON-222 CONCENTRATIONS
LOCATION #806-AMBROSIA LAKE POST OFFICE

On Date Time	Off Date Time	Radon-222 pCi/l	Two Sigma Error Term pCi/l
11/5/75 1525	11/7/75 0830	4.2	0.17
11/7/75 0835	11/9/75 0905	3.9	0.17
11/9/75 0905	11/11/75 0931	1.0	0.089
11/11/75 0932	11/13/75 0820	1.8	0.12
11/13/75 0820	11/15/75 0833	3.1	0.15
11/15/75 0833	11/17/75 0850	3.9	0.16
11/17/75 0850	11/19/75 0903	2.8	0.14
11/19/75 0904	11/21/75 0905	2.5	0.14
11/21/75 0905	11/23/75 0831	5.4	0.21
11/23/75 0832	11/25/75 0903	4.1	0.16
11/25/75 0915	11/27/75 0810	2.0	0.12
11/27/75 0812	11/29/75 1035	1.1	0.086
11/29/75 1040	12/1/75 1015	3.2	0.16
12/1/75 1035	12/3/75 0845	3.9	0.16
<u>Summary</u>			
11/5/75	12/3/75	3.1 (14 Samples)	2.6

TABLE B-8.
AMBIENT OUTDOOR RADON-222 CONCENTRATIONS
LOCATION #807-BLUEWATER

On Date Time	Off Date Time	Radon-222 pCi/l	Two Sigma Error Term pCi/l
11/6/75 0930	11/8/75 0930	1.6	0.11
11/8/75 0935	11/10/75 1700	0.94	0.085
11/10/75 1710	11/12/75 1615	0.59	0.068
11/12/75 1614	11/14/75 0942	1.6	0.11
11/14/75 0942	11/16/75 0843	1.1	0.087
11/16/75 0843	11/18/75 1105	1.8	0.12
11/18/75 1105	11/20/75 1029	0.69	0.074
11/20/75 1030	11/22/75 1035	1.3	0.093
11/22/75 1035	11/24/75 1035	1.3	0.099
11/24/75 1035	11/26/75 1505	0.51	0.061
11/28/75 0935	11/30/75 1530	0.32	0.052
11/30/75 1535	12/2/75 1030	1.7	0.11
<u>Summary</u>			
11/6/75	12/2/75	1.1 (12 Samples)	1.0

TABLE B-9. AMBIENT OUTDOOR RADON-222 CONCENTRATIONS
LOCATION #808-AMBROSIA LAKE TRAILER PARK

On Date Time	Off Date Time	Radon-222 pCi/l	Two Sigma Error Term pCi/l
11/6/75 1040	11/8/75 0818	6.6	0.22
11/8/75 0819	11/9/75 0910	3.3	0.16
11/9/75 0915	11/11/75 0925	2.0	0.12
11/11/75 0930	11/13/75 0810	4.0	0.18
11/13/75 0811	11/15/75 0829	4.2	0.17
11/15/75 0830	11/17/75 0845	4.7	0.18
11/17/75 0845	11/18/75 0700	5.3	0.19
11/18/75 0933	11/20/75 0937	2.7	0.13
11/22/75 0945	11/24/75 0900	4.3	0.17
11/24/75 0905	11/26/75 1320	3.0	0.16
11/26/75 1325	11/28/75 0816	1.3	0.099
11/29/75 1025	11/30/75 1012	1.9	0.12
11/30/75 1015	12/2/75 0953	4.0	0.17
Summary			
11/6/75	12/2/75	3.6 (13 Samples)	3.0

APPENDIX C

METEOROLOGY

Meteorological data for this study were collected from November 4-30, 1975 using a portable mechanical weather station[1] at location #802, east of the United Nuclear-Homestake Partners (UNHP) mill site. Wind speed and direction (3 meters above ground surface) and ambient temperature were continuously recorded at this station. In addition, the official daily high and low temperatures and barometric pressures for the Grants Municipal Airport station were obtained from the U.S. National Weather Service. Unfortunately, confirmation of inversion conditions was not obtainable due to limitations of the mechanical weather station.

Figure C-1 shows the daily temperatures at location #802. A high of 73°F was recorded on November 5 and 17, and a low of minus 8°F on November 30. The average daily maximum and minimum temperature was 54°F and 16°F, respectively, with a monthly (November, 1975) average daily temperature of 32°F. Maximum diurnal variation (57°F) occurred on November 14, with a high of 65°F and a low of 8°F. Minimum diurnal variation (21°F) occurred on November 28, with a high of 51°F and a low of 30°F. These results can be compared to Figure C-2 which shows the daily temperatures recorded at the Grants Municipal Airport. Figure C-3 shows the daily barometric pressure for the airport station.

Precipitation was not quantitatively measured at field location #802 but data were obtained for the Grants Municipal Airport station. Total precipitation for November 1975 consisted of 0.06 inches of rain on the 18th, and on November 29, four inches of snow (0.38 inch rain equivalent) for a total monthly precipitation of 0.44 inches. The official average monthly precipitation for November at Grants is 0.60 inches (U.S. Navy, 1965). Measurements of the November 29 snowfall at several air sampling locations in the Ambrosia Lake area revealed snow depths of seven to nine inches or about twice that measured in Grants.

Figure C-4 is the wind rose plot for field location #802 for November 1975. This plot represents the direction from which the wind was blowing. Roughly one percent of the time the wind was calm, i.e., less than one mile per hour (mph). Predominant winds were from the north to northwest (about 43 percent of the time),

1 Meteorology Research, Inc., Model 1071-Mechanical Weather Station.

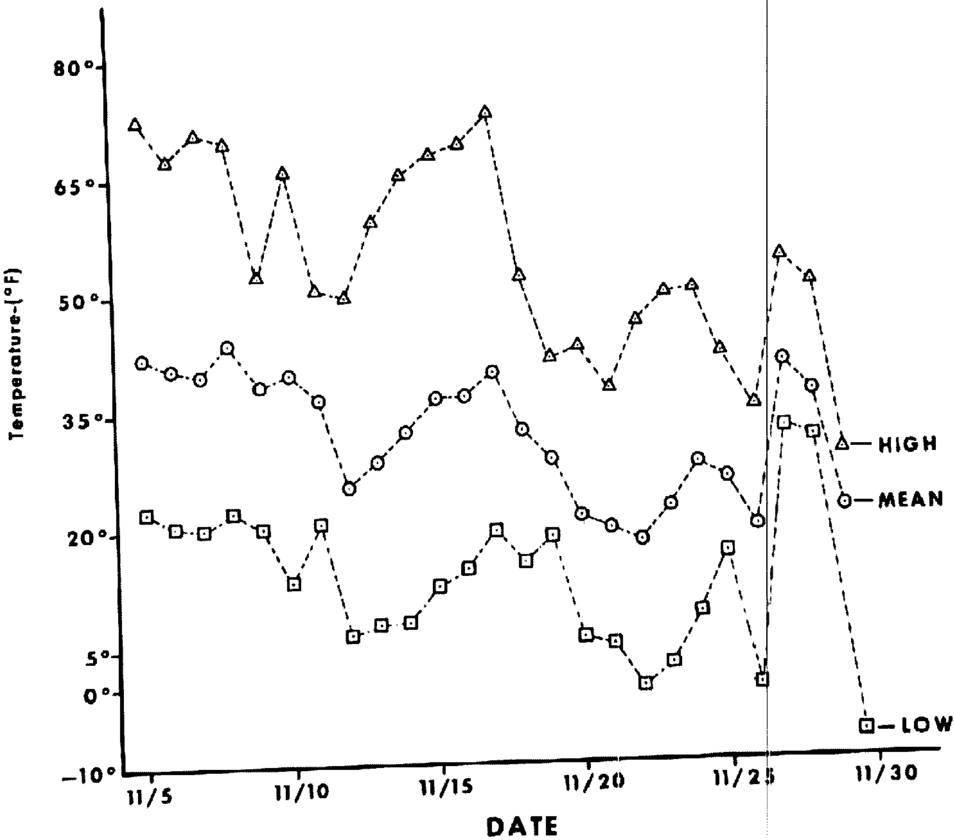

FIGURE C-1. DAILY TEMPERATURES FOR NOVEMBER 1975 AT FIELD LOCATION #802, GRANTS, NEW MEXICO

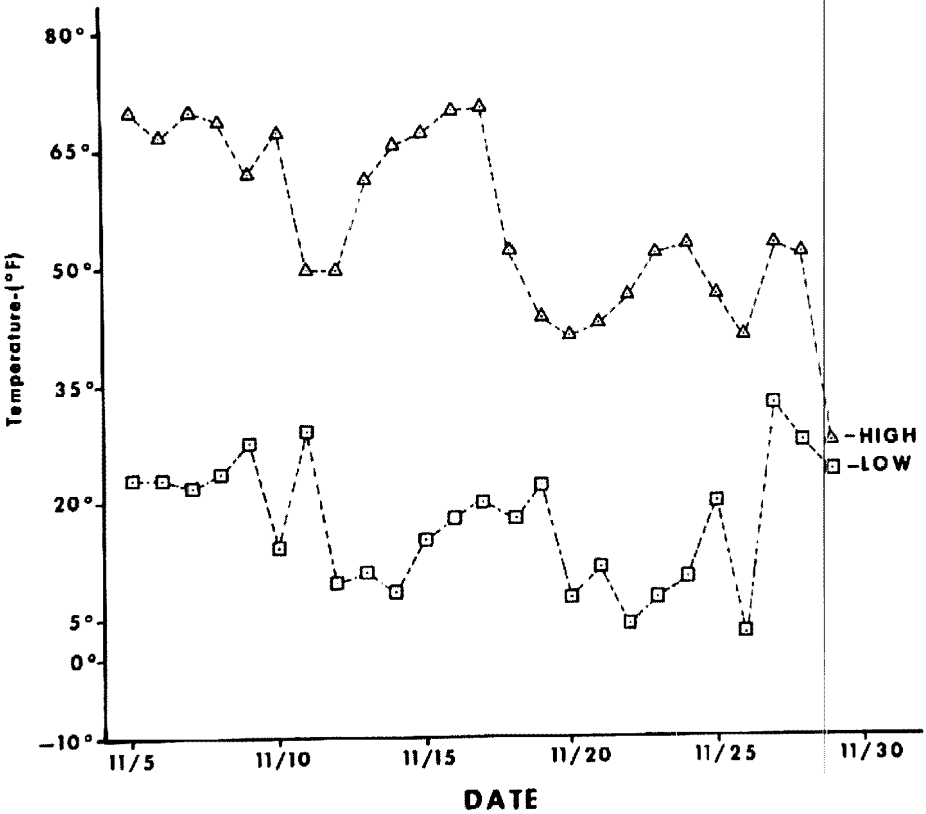

FIGURE C-2. DAILY TEMPERATURES FOR NOVEMBER 1975 AT THE GRANTS MUNICIPAL AIRPORT, NEW MEXICO

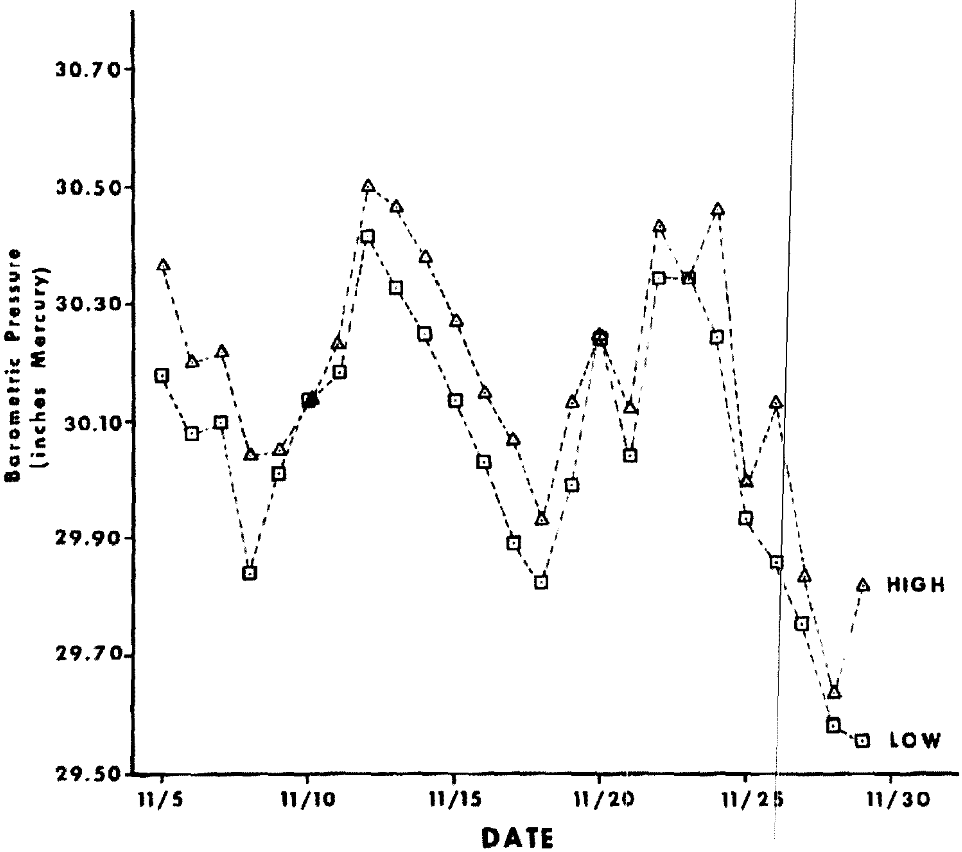

FIGURE C-3. BAROMETRIC PRESSURE FOR NOVEMBER 1975 AT THE GRANTS MUNICIPAL AIRPORT, NEW MEXICO

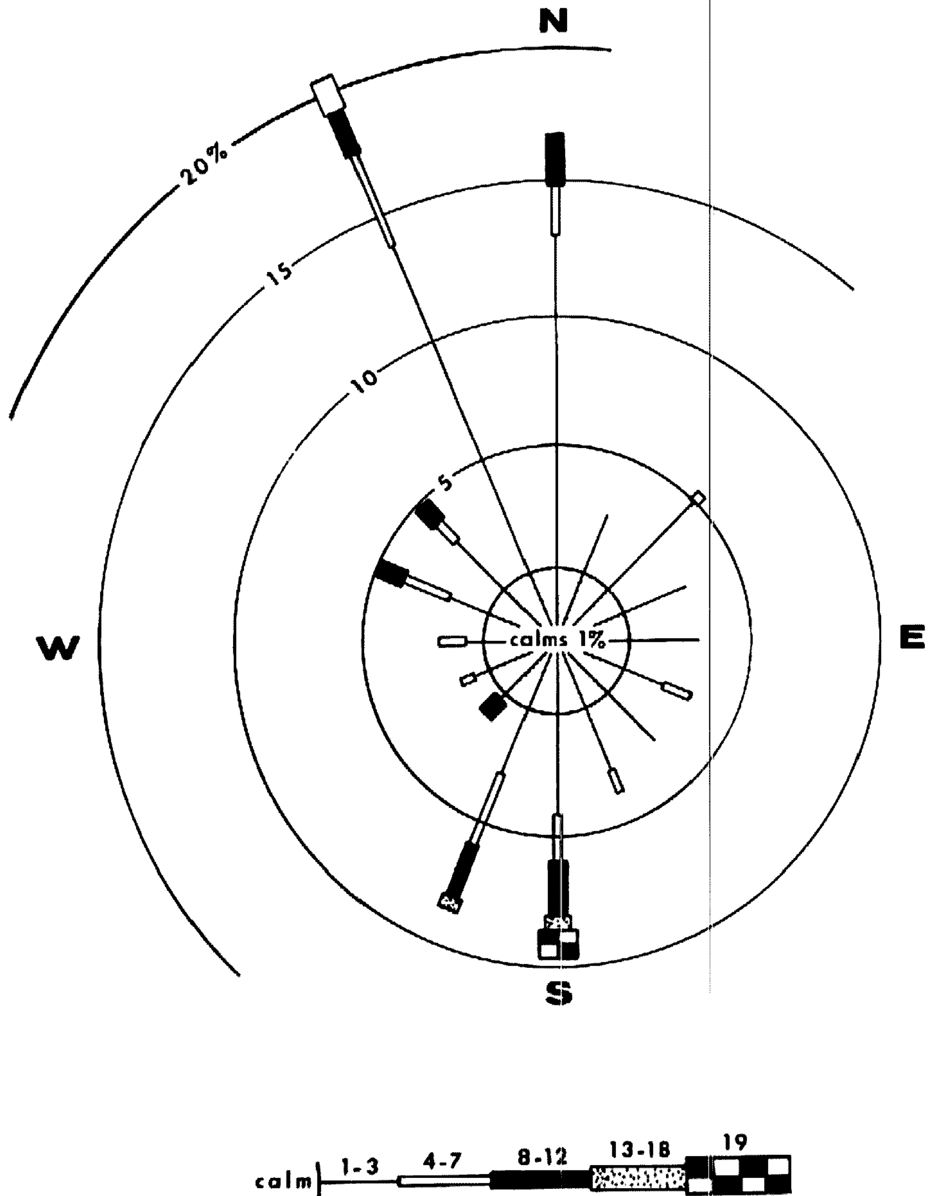

FIGURE C-4. WIND ROSE FOR NOVEMBER 1975 AT FIELD LOCATION #802, GRANTS, NEW MEXICO

APPENDIX D

TABLE D-1. INDOOR RADON PROGENY
Location #800-Milan City Hall

On Date	Off Date	Total Hours	Working Level (WL)
11/04/75	11/10/75	148.7	.01292
11/10/75	11/17/75	164.7	.01420
11/17/75	12/01/75	319.8	.00832
12/01/75	12/03/75	54.1	.01615
Summary			
11/04/75	12/03/75	687.3	0.0129

TABLE D-2. INDOOR RADON PROGENY
Location #801-Bluewater Village

On Date	Off Date	Total Hours	Working Level (WL)
11/04/75	11/08/75	54.5	.00670
11/08/75	11/10/75	23.0	.00213
11/10/75	11/16/75	113.9	.00074
11/16/75	11/20/75	43.7	.00871
11/20/75	11/21/75	14.8	.00657
11/21/75	11/24/75	16.5	.00596
11/24/75	11/26/75	13.5	.00304
11/26/75	11/27/75	7.3	.00555
11/27/75	11/28/75	9.5	.00285
11/28/75	11/30/75	25.1	.00229
11/30/75	12/02/75	6.3	.00433
Summary			
11/04/75	12/02/75	328.1	0.0045

TABLE D-3. INDOOR RADON PROGENY
Location #802-Milan

On Date	Off Date	Total Hours	Working Level (WL)
11/04/75	11/10/75	144.1	.01885
11/10/75	11/15/75	112.8	.00997
11/15/75	11/20/75	120.0	.01300
11/20/75	12/03/75	320.1	.00919
<u>Summary</u>			
11/04/75	12/03/75	697.0	0.0128

TABLE D-4. INDOOR RADON PROGENY
Location #803-Broadview Acres

On Date	Off Date	Total Hours	Working Level (WL)
11/05/75	11/10/75	125.4	.03660
11/10/75	11/15/75	112.8	.02845
11/15/75	11/20/75	120.0	.02832
11/20/75	12/02/75	270.3	.01508
<u>Summary</u>			
11/05/75	12/02/75	628.5	0.0271

TABLE D-5. INDOOR RADON PROGENY
Location #804-Ambrosia Lake Highway Junction

On Date	Off Date	Total Hours	Working Level (WL)
11/05/75	11/07/75	10.6	.01082
11/07/75	11/11/75	72.6	.00538
11/11/75	11/16/75	94.7	.01482
11/16/75	11/17/75	4.4	.00694
11/17/75	11/20/75	24.5	.01432
11/20/75	11/21/75	5.2	.02902
11/21/75	11/24/75	11.1	.00766
11/24/75	11/25/75	10.7	.00532
11/25/75	11/26/75	22.4	.00337
11/26/75	11/28/75	6.5	.00623
11/28/75	11/30/75	26.0	.00131
11/30/75	12/02/75	8.2	.01052
Summary			
11/05/75	12/02/75	296.9	0.0096

TABLE D-6. INDOOR RADON PROGENY
Location #805-San Mateo

On Date	Off Date	Total Hours	Working Level (WL)
11/05/75	11/10/75	122.6	.00305
11/10/75	11/15/75	112.7	.00247
11/15/75	12/01/75	385.2	.00170
Summary			
11/05/75	12/01/75	620.5	0.0024

TABLE D-7. INDOOR RADON PROGENY
Location #806-Ambrosia Lake Post Office

On Date	Off Date	Total Hours	Working Level (WL)
11/05/75	11/10/75	66.3	.03476
11/10/75	11/13/75	68.3	.01605
11/13/75	11/17/75	95.1	.02116
11/17/75	11/20/75	71.0	.02374
11/20/75	11/22/75	47.0	.02794
11/22/75	12/01/75	221.4	.01137
12/01/75	12/03/75	45.9	.04460
<u>Summary</u>			
11/05/75	12/03/75	615.0	0.0257

TABLE D-8. INDOOR RADON PROGENY
Location #807-Bluewater

On Date	Off Date	Total Hours	Working Level (WL)
11/06/75	11/10/75	100.6	.00787
11/10/75	11/15/75	112.6	.00692
11/15/75	11/20/75	120.8	.01068
11/20/75	12/02/75	252.1	.00524
<u>Summary</u>			
11/06/75	12/02/75	586.1	0.0077

TABLE D-9. INDOOR RADON PROGENY
Location #808-Ambrosia Lake Trailer Park

On Date	Off Date	Total Hours	Working Level (WL)
11/06/75	11/09/75	56.9	.02131
11/09/75	11/11/75	43.1	.01450
11/11/75	11/14/75	28.6	.01794
11/14/75	11/19/75	101.8	.01534
11/19/75	11/22/75	47.0	.01071
11/22/75	11/24/75	35.6	.01584
11/24/75	11/26/75	50.7	.01340
11/26/75	12/01/75	97.6	.00485
12/01/75	12/03/75	25.2	.01927
Summary			
11/06/75	12/03/75	486.5	0.0148