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LUCAS HEIGHTS

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ABSTRACT

A survey of radon and radon daughters in the air has been made at and within a few kilometres of the possible uranium mine near Millbillillie at the northern edge of Lake Way, Western Australia. The data have been correlated with meteorological measurements taken concurrently with the radon survey. In addition, radon emanation rates and radon levels in water have been measured at a broad range of sites to define more closely the magnitude and extent of radon in the environment.

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RADON; DAUGHTER PRODUCTS; URANIUM; URANIUM MINES; WESTERN AUSTRALIA; RADIATION MONITORING; URANIUM ORES; GEOLOGIC DEPOSITS; AIR; WATER

CONTENTS

(Continued)

1. INTRODUCTION

From 4 to 17 September 1979, the Australian Atomic Energy Commission (AAEC) measured the radon levels at and in the vicinity of the uranium deposit at the northern end of Lake Way in central Western Australia. Radon and radon daughter levels in air were measured under a variety of weather conditions at sites which were important because of their proximity to local dwellings or possible camp sites. Radon levels in water and surface emanation rates were also measured to provide data upon which to base an assessment of the environmental impact of a mine.

2. EXPERIMENTAL METHODS

2.1 Radon in Air

The two methods used to determine the time-dependent radon concentration in air were based on the same principle. A sample of air was introduced into a chamber, the walls of which were coated with zinc sulphide powder. These chambers are known as 'Lucas cups' [Lucas 1957]. Scintillations produced by the radon and radon daughter alpha particle activity were recorded by a photomultiplier tube.

In the first method, spot samples of air were taken by opening evacuated 90 mL chambers (cups) at the desired location. After standing for about three hours, to permit the decay of any radon daughters present at the time of sampling and to allow the radon to equilibrate with its daughters, the count rate in the cup was measured. The concentration, C, of radon in the cup was then calculated as follows:

$$C(\text{Bq L}^{-1}) = N/(3V\ \eta 2^{-t/91.7}) \quad , \qquad (1)$$

where N = count rate (s^{-1}), V = volume of the cup (L), η = scintillation detector efficiency, and t = time between sampling and counting (h).

This method was the basis for calibration of the second radon measurement device, a continuous monitor set to integrate the radon level over 20-minute periods. Air was drawn at a rate of about 1 L min^{-1} through a filter then through a zinc sulphide-coated cup with a volume of 0.37 L. The cup was mounted on a 125 mm diameter photomultiplier tube, the count rate of which was proportional to the radon level in the air. Calibration measurements showed that the count rate in counts per minute should be divided by 17.2 to yield radon concentration in Bq L^{-1}.

Simple passive dosimeters, manufactured at the AAEC's Research Establishment, Lucas Heights, were used to estimate the average radon level over ten days. These dosimeters consisted of nitrocellulose track-etch film enclosed in a container which permitted the free diffusion of radon but not its daughters.

2.2 Radon Working Levels

The time-dependent level of radon daughters in air was measured using the method of Rolle [1972]. Air was sucked through a Millipore 37 mm x 0.8 µm filter for 10 minutes at 20 L min^{-1}. The filter was then transferred to an alpha particle detection assembly with an efficiency of 30 per cent and counted for 5 minutes, starting 4.35 minutes after sampling was complete.

The working level is given by:

$$WL = (N - B) \times 1.60 \times 10^{-5} \quad , \qquad (2)$$

where N = count in 5 minutes, and B = background count of the detection system.

Average working levels were measured with a dosimeter developed by CEA-STEPPE (APSN Fontenay aux Roses, France). A volume of air, measured by an air integrator (Aichitokei type AP-S), was pumped through a 0.8 µm Millipore filter at a rate of about 1.9 L min^{-1}. Alpha particles from the filter paper passed through two collimators, one of which was covered with a thin Mylar membrane to slow the alpha particles. At the end of the collimator was a track-etch film (Kodak-Pathe LR115) which recorded RaA alpha particles on the section of the film below the open collimator, and RaC' alpha particles from the other collimator on the other section. Background was measured from parts of the film protected by the collimator.

2.3 Surface Emanation Rate

Emanation of radon from the ground was measured by placing a bottomless 200 L drum on the ground, sealing the edges with earth, and measuring the rate at which radon built up in the drum.

Measuring the radon in the drum was done by two methods, the most accurate of which was to take samples of the air in the drum with the small cups, as described in Section 2.1. The cups were returned to the laboratory for counting.

The other method was almost identical in principle, but faster and less accurate in practice. An air sample was drawn through a filter into an INAX model 531 radon counter comprising a zinc sulphide-coated cup, a photomultiplier and counting/timing equipment. This equipment was relatively inaccurate because it yielded a lower count rate for a given quantity of radon, and the background count was higher.

2.4 Radon in Water

Where high accuracy was required, water samples were collected by immersing an evacuated stainless steel container, with its inlet at the required sampling position [Davy et al. 1978]. On activation of a solenoid valve, the water was sucked into the cylinder. The radon in the sample was measured later on the radium/radon rig at Lucas Heights. This will subsequently be referred to as method A.

For most of the water samples, a faster but less accurate method (method B) was used to determine the radon concentration. A number of 800 mL samples were collected in 1 L plastic bottles with a minimum of exposure to air, and a bubbler was inserted into each in turn. Air was circulated through the bubbler and the INAX counter. The major errors associated with this technique (approximately 50 per cent) were due to the background counts in the counter and radon loss during sampling. Calibration of the INAX counter was achieved by sampling from a solution containing a known concentration of radon.

2.5 Meteorological Measurements

Most of the meteorological data presented here were measured by R.K. Steedman and Associates [1980] at the stations shown in Figure 1. Their report contains a more complete record of meteorological conditions at Lake Way.

Additional meteorological data were obtained from an anemometer set 1.5 m above the ground at about the centre of the ore body (4000S, 5000E), and from hand-held directional wind speed indicators. The threshold for these instruments was less than 0.2 m s^{-1}.

2.6 Radon Emanation from Ore Samples

Emanation coefficients were measured by the accumulation of radon in an ingrowth chamber containing a sample of ore. Radon gas concentrations were subsequently determined by α-scintillation counting techniques. The experimental set-up consists of an ingrowth chamber (volume 66 mL), a pump (flowrate 3 L min^{-1}), a sampling cylinder (volume 1060 mL) and connecting pipework.

A sample of ore (1-50 g) was placed in the ingrowth chamber and radon-free air was used to remove all the radon. The ingrowth chamber was then sealed and stored for at least four days to allow the accumulation of radon; the gas was then pumped around the emanation rig for ten minutes to ensure that it was uniformly mixed. The ingrowth chamber was isolated and a known volume of air transferred to an evacuated scintillation cell. The α-activity in the scintillation cell was determined after four hours had been allowed for radon to equilibrate with its daughters. The cells were calibrated using a National Bureau of Standards radium-226 standard source following the recommended method [ASTM 1977].

3. SELECTION OF SITES

For practical purposes, the survey area was divided into a 'mine' area 6 km in diameter and a 'regional' area.

Regional measurement sites are shown in Figure 1, and measurement sites over the ore body are shown on a larger scale in Figure 2. Mine site coordinates of measurement positions are cited in Tables 1-7, except for some regional locations where locally used names such as 'Millbillillie Homestead' or 'Shed Bore' are given.

3.1 Radon in Air and Working Levels

Sites for monitoring were chosen to provide greatest coverage of the mine site and inhabited areas. Since there was little prospect of settlement on the lake itself, least coverage was provided there. Thus the integrating monitors for radon and working levels were stationed at the centre of the mineralised zone (4000S, 5000E), 2.4 km from the centre towards the Aboriginal mission (4250N, 3500E) and 3 km from the centre towards the possible camp sites (250S, 14500E).

The central site was monitored intensively to provide ratios between mine site levels and levels elsewhere. Thus, in addition to the integrating monitors, the continuous radon monitor, an anemometer, and soil temperature thermometers were operated at this site. On most nights, the Rolle method was used to measure spot working levels; a few 90 mL cup samples were also measured as a check on the operation of the continuous radon monitor.

3.2 Surface Emanation Rates

The emanation of radon from the surface was measured mainly to estimate the total emanation from the mine before mining, and compare this with the regional emanation. Thus, regional sites were scattered over a large area. It was also of interest to compare the emanation rates with known uranium mineralisation, surface gamma emission and radon concentration in water. This led to an emphasis on sites at which other measurements had been made. This emphasis in no way affected the value of the measurements as a basis for estimating the average radon emission from the mine area.

3.3 Radon in Water

The radon content of ten water samples was measured by the more accurate method, method A (Section 2.4). These samples were taken from sites across the main zone of uranium mineralisation where measurements had been made of radon emanation, gamma emission and mineralisation.

The less accurate INAX method was used to measure regional water samples from wells and bores up to 14 km from the mine.

4. RESULTS AND DISCUSSION

4.1 Radon and Radon Daughter Concentrations in Air

The concentrations of radon and its daughters in air are presented in Table 1. Included with these data are soil temperatures and local wind conditions. Figures 3 and 4 contain most of these data, as well as wind conditions at the Millbillillie Homestead station and the atmospheric stability index (Appendix A) calculated from the data recorded at the Peanut Lake station. Data in Table 1 not included in Figures 3 and 4 are radon spot levels at the mine centre, close to the continuous monitor. These levels were within 30 per cent of the reading from the continuous monitor, which used a 20 minute averaging period. From this it would appear that the radon levels were generally steady for periods of approximately 20 minutes. Thus spot levels taken at other locations are probably fair estimates of the prevailing radon concentrations and not merely transient values.

The qualitative picture which emerges from Figures 3 and 4, and the average emanation rates (Table 4), is that the mine area is a broadly distributed source of radon, emitting about ten times as much radon as the region beyond about 3 km from the mine centre. Thus the working level at the possible camp site X (11400N, 36000E) was about 0.003 WL when the level at the central site was about 0.03 WL on a day when site X was upwind of the mine. The similarity of working level measurements at sites within about 6 km of the mine site suggests that the fall-off of radon emanation with distance from the mine is only gradual.

It is clear from Figures 3 and 4 that there is a strong qualitative correlation between radon levels, working levels and meteorological parameters. The strongest correlation is with local wind speed near ground level. Whenever the wind speed is less than 0.5 m s^{-1} for a couple of hours, the working levels are at least a factor of four higher than when the wind speed is greater than 1 m s^{-1}.

The atmospheric stability category from sigma theta values is also a good indicator of the presence of radon. On all occasions when the category was F or G (very stable), the radon levels at the central site and working levels were at least a factor of ten higher than the usual value when the category was between A and D. Conversely, on nine of the ten days when the category was between A and D, radon levels were low. The exception, on the

8 September, when there were high radon levels in 'unstable' conditions, is puzzling. It is suggested that this exception occurs infrequently and that the sigma theta method of deriving the stability categories is useful for indicating elevated radon levels at Lake Way.

A third meteorological measurement given in Figures 3 and 4 is wind speed at the Millbillillie Homestead station. This speed is of no predictive value for radon levels. There is insufficient information to assess the predictive value of wind direction.

Quantitative prediction of radon levels is difficult to make with confidence. On the basis of data from most measurements at the central mine site, the working levels could be expected to be between 0.005 and 0.01, and radon levels between 200 and 300 mBq L^{-1} under stable atmospheric conditions. However, the substantially higher values on 13 September (0.037 WL and 700 mBq L^{-1}) provide a basis for predicting much higher levels at this site under category G atmospheric stability, particularly when the wind is from the north. During the two-hour period before dawn on 13 September, radon was building up at a rate of about 180 mBq L^{-1} per hour. At dawn, the working level was 0.037, which corresponded to an equilibrium factor of 0.2. Under a period of twelve hours of extreme stability, which could well occur a few times in the winter months, it is not unreasonable to expect that the radon level would increase to 12 x 180 = 2160 mBq L^{-1} and the working level to 2.16/3.7 = 0.6 WL.

There is no strong indication from Figures 3 and 4 that the radon levels under conditions of prolonged extreme stability would be less than those predicted above, at any of the sites within 6 km of the mine centre. However, beyond 6 km for example, at camp site X (14000N, 36000E), radon levels appear to be substantially less than those in the mine area.

4.2 Radon Emanation Rates and Gamma Emission

The surface emanation rates of radon and the surface gamma-ray emission at several sites are presented in Table 3. In Table 3a are the measurements from the mine area, and in Table 3b the regional measurements. The boundary between 'mine' and 'regional' areas has been arbitrarily set at 3 km from the central monitoring site at 4000S, 5000E.

The quoted errors in the emanation rates are due solely to counting statistics. Reproducibility of measurements at the same time and place was consistent with these errors at the four sites at which duplicate measurements were made. No attempt was made to allow for diurnal variations, which are probably about 20 per cent, as at Yeelirrie, Western Australia [Brownscombe et al. 1978], but may be as much as a factor of four, a variation observed at the uranium mine at Nabarlek in Arnhem Land [Clark et al. 1980]. The values therefore, must be regarded only as a guide to those expected on a given day.

One factor in the selection of sites for emanation rates was the need to sample from areas having varying degrees of uranium mineralisation at various depths. More discussion of the relationship between emanation and mineralisation appears in Section 4.4, but, to summarise, it was not possible to associate emanation rates with any feature of the mine site, except on a very broad scale. The highest readings were within 2 km of the central monitoring station, and the lowest in the regional zone, more than 3 km away. However, only two of the fourteen readings in the regional zone were lower than the lowest reading in the mine zone. In the absence of any pointers for extrapolation of the emanation rates to areas other than the actual measurement sites, the average of all values within any zone was taken to be representative of the entire zone. On the basis of the averages, the emanation rate from the central mine zone (0-2 km) is a factor of six higher than that for the surrounding countryside. The average and total emanation rates for the mine and regional zones are given in Table 4.

4.3 Radon in Water

The concentrations of radon in water samples from bores and wells in regional and mine areas are given in Table 5. With the exception of 'Salt Well', the concentrations were below 690 Bq L^{-1} in all the regional bores and wells, and below 81 Bq L^{-1} in all potable water supplies.

The effect of uranium mineralisation is more marked in the water samples than in surface emanation rates (Section 4.2), with the average concentration of radon being a factor of 17 higher in the mine zone than the regional zone (leaving out the Salt Well results).

4.4 Relationship Between Radon Emanation, Radon in Water, Gamma Emission and Uranium Mineralisation

In making predictions about radon source terms, it is useful to know the correlations between radon emanation and other parameters which may appear to be relevant. Eight sites for the measurement of surface emanation rate were selected to give a variety of degrees of mineralisation at different depths. The surface gamma emission and radon content of water in the bore hole were measured at each site. Table 6 gives the detailed results, and a summary indicating the degree of association of high values of each parameter with high values for the other three.

A parameter is classified as 'high' if it is above the average value for mine site measurements, 'low' if it is below the regional average, and 'medium' if it is in between these averages.

The main conclusion to be drawn from Table 6 is that all four parameters vary independently over a wide range from one position to the next. It would appear that the radium responsible for the measured radon emanation is sufficiently separated from the uranium in which it was formed to remove any correlation between mineralisation and radon levels in the soil over distances of the order of a hundred metres. The lack of correlation between the other parameters reflects the differences in transport mechanisms for radon, radon daughters and gamma rays in soil.

4.5 Radon Emanation Power

The measurements of emanation power and emanation coefficient of radon from twelve representative ore samples are given in Table 7, together with the uranium content.

5. CONCLUSIONS

Measurements of radon daughters in air, made over ten days, have shown that levels are below 0.001 WL under neutral to unstable atmospheric conditions. Within 6 km of the centre of the mine site, levels of about 0.01 WL can be expected during periods of a few hours of highly stable conditions. Longer periods of extreme stability could lead to levels as high as 0.6 WL.

Surface radon emanation rates averaged 0.3 Bq m^{-2} s^{-1} within 2 km of the mine centre, and 0.044 Bq m^{-2} s^{-1} in regional locations. The emanation rates varied by a factor of fifty over the mine site, but by only a factor of five in regional locations.

Radon levels in potable water supplies ranged from 6 to 81 Bq L^{-1} and, in regional bores and wells, up to 690 Bq L^{-1}. The levels in bores in the mine area were much higher, ranging from about 1000 to 10 000 Bq L^{-1}.

6. ACKNOWLEDGEMENTS

The authors wish to thank Dr D.M. Levins of the AAEC for analysing the ore samples and also Mr J. Castelyn for his assistance in the field work. Discussions with Mr D. Davy, also of the AAEC, were invaluable. The friendly cooperation of the denizens of Millbillillie Homestead was greatly appreciated.

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TABLE 1
RADON WORKING LEVELS AND METEOROLOGICAL MEASUREMENTS
AT LAKE WAY FROM SEPTEMBER 5 TO 15, 1979

Explanatory Note

Wind Speeds

(a) 20 minute average
(b) spot measurement

Experimental Errors

(a) Working Levels - less than 10%
(b) Continuous Radon monitor - limit of reading 33 Bq L^{-1}
calibration error 20%
(c) Lucas cup samples - statistical error less than 20%

TABLE 1
RADON WORKING LEVELS AND METEOROLOGICAL MEASUREMENTS AT LAKE WAY FROM SEPTEMBER 5 TO 15, 1979

5.9.79

MINE COORDINATES
4000S 5000E

Time	Radon in Air (cont. radon monitor)		Wind Speed	Time	Radon in Air (cont. radon monitor)		Wind Speed
	$mBq\ L^{-1}$	$pCi\ L^{-1}$	$(m\ s^{-1})$ (a)		$mBq\ L^{-1}$	$pCi\ L^{-1}$	$(m\ s^{-1})$ (a)
0938	33	0.89	2.6	1918	166	4.49	0.4
0958	67	1.82	1.7	1938	200	5.41	0.5
1018	67	1.82	1.9	1958	200	5.41	0.4
1038	0	0.00	1.9	2018	100	2.71	0.5
1058	33	0.89	2.6	2038	200	5.41	0.4
1118	33	0.89	1.7	2058	200	5.41	0.3
1138	33	0.89	1.9	2118	166	4.49	0.6
115[illegible]	67	1.82	2.2	2138	233	6.30	0.3
1218	33	0.89	1.6	2158	166	4.49	0.3
1238	33	0.89	2.0	2218	266	7.19	0.4
1258	33	0.89	2.3	2238	299	8.08	0.3
1318	0	0.00	1.5	2258	299	8.08	0.4
1338	33	0.89	2.0	2318	233	6.30	0.5
1358	0	0.00	1.8	2338	166	4.49	0.5
1418	67	1.82	1.6	2358	266	7.19	0.3
1438	33	0.89	1.9				
1458	67	1.82	1.9				
1518	67	1.82	1.8				
1538	33	0.89	1.4				
1558	33	0.89	1.6				
1618	33	0.89	1.3				
1638	0	0.00	1.8				
1658	67	1.82	0.9				
1718	33	0.89	0.4				
1738	67	1.82	0.3				
1758	100	2.71	0.5				
1818	67	1.82	0.4				
1838	166	4.49	0.4				
1858	133	3.60	0.5				

(Continued)

Time	6.9.79 — Mine Coordinates 4000S 5000E — Radon in Air (cont. radon monitor) mBq L^{-1}	Radon in Air (cont. radon monitor) pCi L^{-1}	Wind Speed (m s^{-1}) (a)	WL $x10^{-3}$	Wind Condition Speed (m s^{-1}) (b)	Wind Condition Direction (°)	Mine Coordinates 4250N 3500E — WL $x10^{-3}$	Wind Condition Speed (m s^{-1}) (b)	Wind Condition Direction (°)
0028	233	6.30	0.3						
0048	233	6.30	0.5	4.0					
0108	266	7.19	0.3	3.0					
0128	266	7.19	0.7	4.0			10.0		
0142	Radon in Air (spot sample)							1305 mBq L^{-1} (35.2 pCi L^{-1})	
0149				4.0			11.0	0.0	
0206	233	6.30	0.2	8.0			11.0		
0226	299	8.08	0.3	7.0			8.0		
0246	233	6.30	0.3	6.0			11.0		
0306	200	5.41	0.5	5.0			7.0		
0326	200	5.41	0.6	5.0			8.0		
0346	166	4.49	0.4	6.0			6.0		
0406	266	7.19	0.2	5.0			13.0		
0426	200	5.41	0.5	6.0			9.0		
0447	299	8.08	0.3	4.0			10.0		
0500	Radon in Air (spot sample)							1752 mBq L^{-1} (47.4 pCi L^{-1})	
0507	200	5.41	0.3	0.3			10.0	0.0	
0527	166	4.49	0.3	4.0			13.0		
0547	133	3.60	0.4	4.0			11.0		
0607	133	3.60	0.2	4.0			13.0		
0627	432	11.68	0.2	7.0			13.0		
0647	166	4.49	0.7	7.0			6.0	0.8	190
0707	100	2.71	0.9						
0727	100	2.71	1.1						
0747	67	1.82	1.9						
0807	33	0.89	1.8						
0827	67	1.82	1.7						
0847	100	2.71	1.8						

(Continued)

6.9.79							
MINE COORDINATES 4000S 5000E							
Time	Radon in Air (cont. radon monitor)		Wind Speed	Time	Radon in Air (cont. radon monitor)		Wind Speed
	mBq L^{-1}	pCi L^{-1}	(m s^{-1}) (a)		mBq L^{-1}	pCi L^{-1}	(m s^{-1}) (a)
0907	33	0.89	1.7	1807	67	1.82	0.4
0927	67	1.82	1.6	1827	100	2.71	0.4
0947	33	0.89	1.7	1847	67	1.82	0.3
1007	33	0.89	2.0	1907	100	2.71	0.3
1027	33	0.89	2.1	1927	100	2.71	0.6
1047	33	0.89	1.4	1947	200	5.41	0.5
1107	33	0.89	1.8	2007	233	6.30	0.5
1127	33	0.89	1.7	2027	166	4.49	0.5
1147	67	1.82	1.9	2047	100	2.71	0.4
1207	33	0.89	1.7	2107	166	4.49	0.4
1227	0	0.00	2.1	2127	166	4.49	0.4
1247	0	0.00	1.6	2147	299	8.08	0.6
1307	33	0.89	2.0	2207	233	6.30	0.5
1327	33	0.89	1.9	2227	299	8.08	0.5
1347	33	0.89	1.9	2247	266	7.19	0.5
1407	33	0.89	1.6	2307	166	4.49	0.5
1427	33	0.89	2.1	2327	332	8.97	0.4
1447	33	0.89	1.6	2347	299	8.08	0.5
1507	100	2.71	1.6				
1527	67	1.82	1.8				
1547	0	0.00	1.7				
1607	100	2.71	1.5				
1627	33	0.89	1.7				
1647	67	1.82	1.7				
1707	67	1.82	1.3				
1727	0	0.00	0.9				
1747	0	0.00	0.4				

(Continued)

7.9.79									
MINE COORDINATES 4000S 5000E				MINE COORDINATES 14000N 15000E			MINE COORDINATES 4250N 3500E		
Time	Radon in Air (cont. radon monitor)		Wind Speed	WL $\times 10^{-3}$	Wind Condition		WL $\times 10^{-3}$	Wind Condition	
	$mBq\ L^{-1}$	$pCi\ L^{-1}$	$(m\ s^{-1})$ (a)		Speed $(m\ s^{-1})$ (b)	Direction (°)		Speed $(m\ s^{-1})$ (b)	Direction (°)
0007	299	8.08	0.5						
0027	332	8.97	0.3						
0047	332	8.97	0.3	15.0			10.0		
0107	299	8.08	0.3	12.0			11.0		
0127	266	7.19	0.5	5.0			9.0		
0147	399	10.79	0.4	8.0	0.03	202	10.0		
0153	Radon in Air (spot sample)						729 $mBq\ L^{-1}$ (19.7 $pCi\ L^{-1}$)		
0207	233	6.30	0.3	6.0			11.0		
0210	Radon in Air (spot sample)						1211 $mBq\ L^{-1}$ (32.7 $pCi\ L^{-1}$)		
0227	233	6.30	0.3	9.0			13.0		
0247	266	7.19	0.4	13.0			13.0		
0307	332	8.97	0.3	9.0			16.0		
0327	233	6.30	0.6	11.0			16.0		
0347	200	5.41	0.4	15.0			18.0		
0355	Radon in Air (spot sample)						1231 $mBq\ L^{-1}$ (33.3 $pCi\ L^{-1}$)		
0407	299	8.08	0.2	20.0			21.0		
0427	299	8.08	0.4	15.0			16.0		
0449	233	6.30	0.3	12.0			12.0		
0509	299	8.08	0.7	19.0			11.0		
0529	266	7.19	0.4	13.0			12.0		
0549	266	7.19	0.3	9.0			12.0		
0609	332	8.97	0.6	9.0			13.0		
0629	233	6.30	0.6				18.0		
0649	332	8.97	0.3				18.0		
0709	466	12.60	0.8				16.0		
0729	266	7.19	0.9						

(Continued)

7.9.79

MINE COORDINATES
4000S 5000E

Time	Radon in Air (cont. radon monitor)		Wind Speed	Time	Radon in Air (cont. radon monitor)		Wind Speed
	mBq L^{-1}	pCi L^{-1}	(m s^{-1}) (a)		mBq L^{-1}	pCi L^{-1}	(m s^{-1}) (a)
0749	266	7.19	0.8	1724	33	0.89	1.0
0809	166	4.49	1.0	1744	100	2.71	0.8
0829	166	4.49	1.2	1804	67	1.82	0.8
0849	100	2.71	2.0	1824	133	3.60	0.6
0909	100	2.71	2.3	1844	100	2.71	1.0
0929	100	2.71	2.8	1904	100	2.71	1.2
0949	67	1.82	3.1	1924	100	2.71	1.1
1009	33	0.89	3.2	1944	100	2.71	1.1
1029	67	1.82	2.9	2004	100	2.71	1.4
1049	33	0.89	3.1	2024	100	2.71	1.5
1109	67	1.82	2.7	2044	133	3.60	1.5
1129	33	0.89	3.0	2104	33	0.89	1.6
1149	0	0.00	2.2	2124	133	3.60	1.5
1204	67	1.82	2.6	2144	67	1.82	2.3
1224	33	0.89	2.5	2204	67	1.82	2.4
1244	33	0.89	2.3	2224	67	1.82	2.3
1304	33	0.89	2.0	2244	67	1.82	2.6
1324	67	1.82	2.0	2304	100	2.71	2.3
1344	33	0.89	2.2	2324	67	1.82	2.2
1404	33	0.89	2.1	2344	67	1.82	2.0
1424	33	0.89	2.5				
1444	67	1.82	2.6				
1504	0	0.00	2.2				
1524	33	0.89	2.0				
1544	67	1.82	1.7				
1604	33	0.89	1.2				
1624	0	0.00	1.7				
1644	33	0.89	1.5				
1704	67	1.82	1.7				

(Continued)

8.9.79									
	MINE COORDINATES 4000S 5000E			MINE COORDINATES 14000N 5000E			MINE COORDINATES 250S 14500E		
Time	Radon in Air (cont. radon monitor)		Wind speed	WL x10^{-3}	Wind Condition		WL x10^{-3}	Wind Condition	
	mBq L^{-1}	pCi L^{-1}	(m s^{-1}) (a)		Speed (m s^{-1}) (a)	Direction (°)		Speed (m s^{-1}) (b)	Direction (°)
0004	33	0.89	2.1						
0024	33	0.89	2.1						
0044	33	0.89	1.9	0.8	1.0	22	0.9	1.3	0
0100	33	0.89	1.5	1.2			0.6		
0122	67	1.82	1.0	1.2			0.7		
0142	33	0.89	0.6	1.5			1.1		
0203	67	1.82	0.2	2.0		22	1.0		Fluky
0224	133	3.60	0.3	1.7			0.6		
0246	133	3.60	0.3	2.2			0.7		
0306	100	2.71	0.4	1.7	0.0		1.8		
0326	166	4.49	0.7	1.2			2.6		
0346	133	3.60	0.5	1.8			2.3		
0400	Radon in Air (spot sample)						143 mBq L^{-1} (3.9 pCi L^{-1})		
0406	233	6.30	0.3	4.0		22	1.9	0.0	
0426	299	8.08	0.3	1.9			2.5		
0446	266	7.19	0.3	3.5			6.5		
0506				2.5		22			
0520	Radon in Air (spot sample) 307 mBq L^{-1} (8.3 pCi L^{-1})								
0526	299	8.08	0.3	3.4			2.1		
0531	Radon in Air (spot sample) 282 mBq L^{-1} (7.6 pCi L^{-1})						150 mBq L^{-1} (4.1 pCi L^{-1})		
0546	432	11.68	0.3	2.5			1.8		
0600	Radon in Air (spot sample)						130 mBq L^{-1} (3.1 pCi L^{-1})		
0606	366	9.90	0.7	1.2			1.4	1.1	22
0626	133	3.60	1.2	1.2			1.6		
0646	100	2.71	1.4	1.6			1.5		
0706	133	3.60	1.9						
0726	100	2.71	2.5						

(Continued)

8.9.79							
MINE COORDINATES 4000S 5000E							
Time	Radon in Air (cont. radon monitor)		Wind Speed	Time	Radon in Air (cont. radon monitor)		Wind Speed
	$mBq\ L^{-1}$	$pCi\ L^{-1}$	$(m\ s^{-1})$ (a)		$mBq\ L^{-1}$	$pCi\ L^{-1}$	$(m\ s^{-1})$ (a)
0746	33	0.89	3.0	1702	33	0.89	2.6
0806	100	2.71	3.0	1722	33	0.89	2.7
0826	33	0.89	3.0	1742	0	0.00	2.5
0846	33	0.89	3.1	1802	0	0.00	2.2
0906	33	0.89	3.2	1822	0	0.00	1.8
0926	67	1.82	2.6	1842	33	0.89	1.5
0946	33	0.89	2.5	1902	33	0.89	1.4
1006	33	0.89	2.5	1922	0	0.00	1.3
1026	33	0.89	3.0	1942	33	0.89	1.2
1046	33	0.89	3.0	2002	0	0.00	1.3
1106	33	0.89	3.0	2022	0	0.00	1.0
1126	33	0.89	2.9	2042	33	0.89	1.1
1146	33	0.89	2.9	2102	0	0.00	0.9
1202	0	0.00	3.4	2122	0	0.00	0.8
1222	67	1.82	3.7	2142	0	0.00	1.1
1242	0	0.00	3.6	2202	33	0.89	1.2
1302	0	0.00	3.8	2222	33	0.89	1.2
1322	33	0.89	3.9	2242	33	0.89	1.3
1342	33	0.89	3.6	2302	0	0.00	1.4
1402	33	0.89	3.7	2322	33	0.89	1.4
1422	33	0.89	3.7	2342	33	0.89	1.3
1442	33	0.89	3.9				
1502	67	1.82	4.0				
1522	33	0.89	3.4				
1542	33	0.89	3.2				
1602	33	0.89	3.7				
1622	33	0.89	3.4				
1642	33	0.89	3.3				

(Continued)

9.9.79									
	MINE COORDINATES 4000S 5000E			MINE COORDINATES 8000N 23200E			MINE COORDINATES (Possible Campsite X) 11400N 36000E		
Time	Radon in Air (cont. radon monitor)		Wind Speed	WL $x10^{-3}$	Wind Condition		WL $x10^{-3}$	Wind Condition	
	$mBq\ L^{-1}$	$pCi\ L^{-1}$	$(m\ s^{-1})$ (a)		Speed $(m\ s^{-1})$ (b)	Direction (°)		Speed $(m\ s^{-1})$ (b)	Direction (°)
0006	0	0.00	1.3						
0026	33	0.89	1.4	0.6			0.8	0.7	270
0046	0	0.00	1.2	1.3			1.2		
0106	33	0.89	1.3	1.0			1.3		
0126	33	0.89	1.3	0.6	0.9	270	0.5		
0130	Radon in Air (spot sample)						68 $mBq\ L^{-1}$ (1.8 $pCi\ L^{-1}$)		
0146	33	0.89	1.5	1.3			0.6	0.9	337
0208	0	0.00	1.6	1.0			0.9		
0228	0	0.00	1.9	1.2			1.4		
0248	33	0.89	1.0	1.3			0.9	0.7	225
0308	33	0.89	1.6						
0322	33	0.89	2.0	1.7		270	0.8		
0330	Radon in Air Concentration			86 $mBq\ L^{-1}$ (2.3 $pCi\ L^{-1}$)			113 $mBq\ L^{-1}$ (3.1 $pCi\ L^{-1}$)		
0342	0	0.00	1.9	1.8			2.3	0.5	270
0402	33	0.89	1.9				1.4		
0422	67	1.82	1.4	2.0			1.4	0.0	
0442	0	0.89	1.8				2.1		
0502	0	0.00	1.7	2.4			2.8		
	Radon in Air (spot sample)						155 $mBq\ L^{-1}$ (4.2 $pCi\ L^{-1}$)		
0522	33	0.89	1.2				3.0		
0530	Radon in Air (spot sample)						131 $mBq\ L^{-1}$ (3.5 $pCi\ L^{-1}$)		
0542	33	0.89	1.6	1.8			2.8		
0602	0	0.00	1.3				2.3	0.3	270
0605	Radon in Air (spot sample)						181 $mBq\ L^{-1}$ (4.9 $pCi\ L^{-1}$)		
0625	67	1.82	1.9				2.3		
0645	0	0.00	2.9				1.9		
0705	33	0.89	4.0				1.4		

(Continued)

9.9.79							
MINE COORDINATES 4000S 5000E							
Time	Radon in Air (cont. radon monitor)		Wind Speed	Time	Radon in Air (cont. radon monitor)		Wind Speed
	$mBq\ L^{-1}$	$pCi\ L^{-1}$	$(m\ s^{-1})$ (a)		$mBq\ L^{-1}$	$pCi\ L^{-1}$	$(m\ s^{-1})$ (a)
0722	67	1.82	5.1	1638	33	0.89	5.6
0742	33	0.89	5.4	1658	33	0.89	6.2
0802	0	0.00	5.0	1718	0	0.00	5.8
0822	33	0.89	5.5	1738	67	1.82	5.4
0842	0	0.00	5.4	1758	33	0.89	5.2
0902	33	0.89	5.6	1818	33	0.89	4.7
0922	33	0.89	5.1	1838	33	0.89	4.0
0942	33	0.89	5.0	1858	0	0.00	3.4
1002	0	0.00	5.2	1918	33	0.89	2.8
1022	0	0.00	5.7	1938	33	0.89	2.6
1042	0	0.00	5.0	1958	0	0.00	2.5
1102	0	0.00	5.3	2018	33	0.89	2.7
1122	0	0.00	5.7	2038	67	1.82	4.2
1142	33	0.89	4.8	2058	33	0.89	5.0
1218	33	0.89	5.3	2118	67	1.82	4.9
1238	33	0.89	5.3	2138	100	2.71	6.0
1258	33	0.89	5.5	2158	33	0.89	5.8
1318	33	0.89	5.6	2218	67	1.82	4.3
1338	33	0.89	5.5	2238	67	1.82	4.3
1358	0	0.00	6.5	2258	33	0.89	3.7
1418	33	0.89	5.8	2318	67	1.82	4.6
1438	33	0.89	5.0	2338	67	1.82	4.3
1458	0	0.00	6.1	2358	67	1.82	4.6
1518	0	0.00	6.2				
1538	0	0.00	6.3				
1558	33	0.89	5.6				
1618	0	0.00	5.3				

(Continued)

10.9.79											
MINE COORDINATES 4000S 5000E									MINE COORDINATES 4000S 15000E		
Time	Radon in Air (cont. radon monitor)		Wind Speed	Soil Temperature (°)		WL $\times 10^{-3}$	Wind Condition		WL $\times 10^{-3}$	Wind Condition	
	mBq L^{-1}	pCi L^{-1}	(m s^{-1} (a)	-5cm	-15cm		Speed (m s^{-1}) (b)	Direction (°)		Speed (m s^{-1}) (b)	Direction (°)
0018	33	0.89	5.2								
0038	33	0.89	4.7								
0054				15.6	19.0	0.4					
0117	33	0.89	5.7			0.2			0.4		
0138	33	0.89	4.1			0.4			0.4		
0200	33	0.89	4.6			0.4			0.4	3.5	202
0220	67	1.82	5.2			0.4			0.4		
0242	67	1.82	5.8			0.4			0.6		
0303	67	1.82	4.8	13.6	18.5	0.4			0.3		
0323	67	1.82	3.4			0.4			0.6	3.0	202
0344	33	0.89	3.8			0.4			0.3		
0406	100	2.71	3.6			0.4			0.2		
0426	67	1.82	2.7			0.5			0.1		
0446	100	2.71	1.2			0.5			0.3		
0500	33	0.89	0.6	12.1	18.3	0.6			0.3		
0525	33	0.89	2.0			0.4	0.3	180	0.5	1.3	225
0526	Radon in Air (spot sample)								64 mBq L^{-1} (1.7 pCi L^{-1})		
0535	Radon in Air (spot sample)								89 mBq L^{-1} (2.4 pCi L^{-1})		
0545	67	1.82	2.7			0.3	1.2	180	0.4	0.7	225
0605	100	2.71	2.9			0.2			0.5		
0625	67	1.82	2.7			0.2	2.0	180	0.3		
0645	33	0.89	4.2	11.4	18.0						
0705	67	1.82	5.1								
0725	100	2.71	5.7								
0745	67	1.82	6.3								
0805	67	1.82	6.2								
0825	67	1.82	6.4								

(Continued)

10.9.79

MINE COORDINATES
4000S 5000E

Time	Radon in Air (cont. radon monitor)		Wind Speed	Time	Radon in Air (cont. radon monitor)		Wind Speed
	mBq L^{-1}	pCi L^{-1}	(m s^{-1}) (a)		mBq L^{-1}	pCi L^{-1}	(m s^{-1}) (a)
0841	67	1.82	6.0	1741	100	2.81	2.3
0901	33	0.89	6.1	1801	33	0.89	2.4
0921	67	1.82	5.5	1821	67	1.82	2.3
0941	67	1.82	5.0	1841	67	1.82	1.8
1001	67	1.82	5.3	1901	100	2.71	1.9
1921	33	0.89	5.5	1921	67	1.82	1.5
1041	33	0.89	5.6	1941	100	2.71	1.1
1101	33	0.89	5.5	2001	67	1.82	0.5
1121	0	0.00	5.5	2021	166	4.49	0.5
1141	0	0.00	4.8	2041	67	1.82	0.3
1201	100	2.71	4.6	2101	100	2.71	0.2
1221	67	1.82	4.8	2121	100	2.71	0.3
1241	67	1.82	4.8	2141	100	2.71	0.1
1301	100	2.71	4.5	2201	133	3.60	0.2
1321	67	1.82	4.5	2221	133	3.60	0.3
1341	67	1.82	4.1	2241	200	5.41	0.2
1401	0	0.00	4.3	2301	200	5.41	0.3
1421	67	1.82	4.4	2321	200	5.41	0.2
1441	33	0.89	4.5	2341	200	5.41	0.1
1501	67	1.82	4.5				
1521	100	2.71	4.1				
1541	33	0.89	4.0				
1601	33	0.89	3.7				
1621	33	0.89	3.5				
1641	67	1.82	3.9				
1701	100	2.71	3.7				
1721	33	0.89	3.1				

(Continued)

11.9.79											
MINE COORDINATES 4000S 5000E									MINE COORDINATES 2000N 4000W		
Time	Radon in Air (cont. radon monitor)		Wind Speed	Soil Temperature (°)		WL x10^{-3}	Wind Condition		WL x10^{-3}	Wind Condition	
	mBq L^{-1}	pCi L^{-1}	(m s^{-1}) (a)	-5cm	-15cm		Speed (m s^{-1}) (b)	Direction (°)		Speed (m s^{-1}) (b)	Direction (°)
0001	200	5.41	0.1								
0021	200	5.41	0.1								
0041	233	6.30	0.2								
0101	200	5.41	0.2	15.6	19.0	4.0					
0121	233	6.30	0.2			5.0			2.0	0.4	157
0130	Radon in Air (spot sample)								41 mBq L^{-1}(1.1 pCi L^{-1})		
0141	200	5.41	0.3			6.0			2.0		
0201	299	8.08	0.6			5.0			2.0		
0221	166	4.49	0.7			4.0			2.0		
0241	233	6.30	0.7			4.0			2.0	0.5	157
0301	133	3.60	0.4	13.6	18.5	5.0			1.0		
0321	266	7.19	0.4			5.0			3.0		
0341	133	3.60	0.5			9.0			4.0		
0400	Radon in Air (spot sample)								116 mBq L^{-1}(3.1 pCi L^{-1})		
0401	299	8.08	0.7			6.0			2.0		
0421	200	5.41	0.4			6.0			3.0		
0441	200	5.41	0.4			4.0			2.0	0.4	157
0501	200	5.41	0.3	12.1	18.3	5.0			5.0		
0521	200	5.41	0.5			5.0	0.3	157	5.0		
0540	Radon in Air Concentration 150 mBq L^{-1}(4.0 pCi L^{-1})								81 mBq L^{-1}(2.2 pCi L^{-1})		
0541	233	6.30	0.4			8.0			4.0	0.3	157
0555	Radon in Air (spot sample)								224 mBq L^{-1}(6.0 pCi L^{-1})		
0601	266	7.19	0.3			9.0			6.0		
0622	133	3.60	0.3			8.0			6.0		
0623	Radon in Air (spot sample)								163 mBq L^{-1}(4.4 pCi L^{-1})		
0642	166	4.49	0.8	11.4	18.0	6.0			4.0		
0702	100	2.71	1.2			6.0					

(Continued)

11.9.79								
MINE COORDINATES 4000S 5000E								
Time	Radon in Air (cont. radon monitor)		Wind Speed		Time	Radon in Air (cont. radon monitor)		Wind Speed
	$mBq\ L^{-1}$	$pCi\ L^{-1}$	$(m\ s^{-1})$ (a)			$mBq\ L^{-1}$	$pCi\ L^{-1}$	$(m\ s^{-1})$ (a)
0725	133	3.60	1.7		1625	0	0.00	3.4
0745	100	2.71	2.0		1645	0	0.00	3.2
0805	100	2.71	2.5		1705	0	0.00	3.0
0825	67	1.82	3.5		1725	33	0.89	2.6
0845	100	2.71	3.8		1745	0	0.00	2.1
0905	33	0.89	4.1		1805	33	0.89	1.8
0925	33	0.89	4.3		1825	0	0.00	1.6
0945	67	1.82	3.7		1845	33	0.89	1.4
1005	67	1.82	4.0		1905	33	0.89	1.3
1025	0	0.00	3.0		1925	33	0.89	1.2
1045	33	0.89	3.6		1945	33	0.89	1.2
1105	67	1.82	3.8		2005	33	0.89	1.0
1125	0	0.00	3.4		2025	67	1.82	0.9
1145	0	0.00	3.3		2045	0	0.00	1.2
1205	33	0.89	3.4		2105	33	0.89	1.2
1225	33	0.89	3.5		2125	0	0.00	1.2
1245	0	0.00	3.6		2145	33	0.89	1.0
1305	67	1.82	3.7		2205	33	0.89	0.5
1325	0	0.00	3.3		2225	33	0.89	0.2
1345	33	0.89	3.8		2245	67	1.82	0.3
1405	0	0.00	3.3		2305	67	1.82	0.3
1425	0	0.00	3.9		2325	33	0.89	0.3
1445	33	0.89	3.1		2345	100	2.71	0.4
1505	0	0.00	3.9					
1525	33	0.89	3.4					
1545	33	0.89	3.1					
1605	0	0.00	3.3					

(Continued)

12.9.79											
MINE COORDINATES 4000S 5000E									MINE COORDINATES 14000N 5000E		
Time	Radon in Air (cont. radon monitor)		Wind Speed	Soil Temperature (°)		WL $\times 10^{-3}$	Wind Condition		WL $\times 10^{-3}$	Wind Condition	
	mBq L^{-1}	pCi L^{-1}	($m\ s^{-1}$) (a)	-5cm	-15cm		Speed ($m\ s^{-1}$) (b)	Direction (°)		Speed ($m\ s^{-1}$) (b)	Direction (°)
0005	100	2.71	0.2								
0025	100	2.71	0.4								
0045	133	3.60	0.3			4.0					
0105	67	1.82	0.4			5.0			3.0		
0125	200	5.41	0.2			6.0			3.0		
0145	166	4.49	0.4			4.0			6.0	0.0	
0205						4.0			6.0		
0225	266	7.19	0.4	10.4	17.4				5.0		
0231						4.0			4.0	0.3	225
0245	332	8.97	0.2			6.0			6.0		
0306	233	6.30	0.4			4.0			5.0		
0326	233	6.30	0.5			5.0			6.0		
0346	233	6.30	0.3						6.0		
0352						5.0			6.0		
0408	233	6.30	0.3			6.0			8.0		
0428	233	6.30	0.2	9.3	16.9	12.0			8.0		
0430	Radon in Air (spot sample)										161 mBq L^{-1} (4.3 pCi L^{-1})
0448	233	6.30	0.2			10.0			8.0		
0505	Radon in Air (spot sample)										216 mBq L^{-1} (5.8 pCi L^{-1})
0508	233	6.30	0.2			12.0			5.0		
0522									5.0		
0528	332	8.97	0.4			10.0					
0535	Radon in Air (spot sample)										247 mBq L^{-1} (6.7 pCi L^{-1})
0548	233	6.30	0.3						9.0		
0555						11.0			6.0		
0608	200	5.41	0.4			6.0			10.0		
0615	Radon in Air (spot sample)										171 mBq L^{-1} (4.6 pCi L^{-1})
0628	200	5.41	0.4			7.0			7.0		
0648	233	6.30	0.4			6.0			10.0		
0708	200	5.41	0.9			5.0			6.0		

(Continued)

12.9.79							
MINE COORDINATES 4000S 5000E							
Time	Radon in Air (cont. radon monitor)		Wind Speed	Time	Radon in Air (cont. radon monitor)		Wind Speed
	mBq L^{-1}	pCi L^{-1}	(m s^{-1}) (a)		mBq L^{-1}	pCi L^{-1}	(m s^{-1}) (a)
0724	100	2.71	1.5	1604	67	1.82	2.8
0744	100	2.71	1.9	1624	67	1.82	2.5
0804	33	0.89	2.5	1644	33	0.89	2.3
0824	33	0.89	2.8	1704	33	0.89	2.2
0844	100	2.71	2.8	1724	67	1.82	2.0
0904	33	0.89	3.1	1744	100	2.71	1.0
0924	67	1.82	3.1	1804	67	1.82	0.3
0944	33	0.89	3.0	1824	100	2.71	0.3
1004	33	0.89	2.7	1844	133	3.60	0.2
1024	33	0.89	2.7	1904	67	1.82	0.4
1044	33	0.89	2.9	1924	100	2.71	0.4
1104	33	0.89	2.8	1944	100	2.71	0.6
1124	0	0.00	2.7	2004	67	1.82	0.5
1144	33	0.89	2.5	2024	100	2.71	0.6
1204	33	0.89	2.4	2044	67	1.82	0.4
1224	67	1.82	2.4	2104	166	4.49	0.3
1244	67	1.82	2.5	2124	233	6.30	0.3
1304	67	1.82	2.3	2144	166	4.49	0.3
1324	67	1.82	1.8	2204	233	6.30	0.3
1344	67	1.82	2.3	2224	299	8.08	0.3
1404	67	1.82	1.8	2244	299	8.08	0.2
1424	33	0.89	2.1	2304	299	8.08	0.4
1444	67	1.82	1.9	2324	233	6.30	0.6
1504	67	1.82	2.1	2344	332	8.97	0.4
1524	67	1.82	1.6				
1544	67	1.82	1.7				

(Continued)

13.9.79											
MINE COORDINATES 4000S 5000E									MINE COORDINATES (Possible Camp Site X) 11400N 36000E		
Time	Radon in Air (cont. radon monitor)		Wind Speed	Soil Temperature (°)		WL X10^{-3}	Wind Condition		WL x10^{-3}	Wind Condition	
	mBq L^{-1}	pCi L^{-1}	(m s^{-1}) (a)	-5cm	-15cm		Speed (m s^{-1}) (b)	Direction (°)		Speed (m s^{-1}) (b)	Direction (°)
0004	299	8.08	0.6								
0024	366	9.90	0.4								
0044	233	6.30	0.2						0.4		
0104	233	6.30	0.2	12.8	18.7	5.6			1.4	0.7	45
0132	366	9.90	0.2	12.4	18.5	5.6			0.9		
0152	200	5.41	0.6	12.1	18.5	6.1			1.6		
0212	399	10.79	0.3			8.3	0.4	0	2.2		
0232	233	6.30	0.3	11.4	18.3	10.4			0.9		
0254	266	7.19	0.2	11.4	18.1	7.3			3.8	0.0	
0315	332	8.97	0.4			6.9			5.2		
0336	432	11.68	0.5	11.2	18.0	14.5			3.2		
0356	299	3.08	0.2	10.8	17.8	26.5			3.6		
0405	Radon in Air (spot sample)								352 mBq L^{-1} (9.5 pCi L^{-1})		
0416	299	8.08	0.4			20.3			3.5		
0436	432	11.68	0.2	10.7	17.8	17.9			3.5		
0440	Radon in Air (spot sample)								405 mBq L^{-1} (10.9 pCi L^{-1})		
0456	532	14.38	0.3	10.3	17.6	28.6			2.5	0.0	
0516	665	17.98	0.3			34.8			3.5		
0536	699	18.90	0.3	10.1	17.5	36.8			3.8		
0556	632	17.09	0.2	9.8	17.3	34.7			1.7		
0600	Radon in Air (spot sample)								552 mBq L^{-1} (14.9 pCi L^{-1})		
0616	565	15.27	0.2			21.5			3.0		
0636	432	11.68	0.2	9.8	17.3	18.8			2.9		
0656	499	13.49	0.5	10.0	17.3	13.3			3.1		
0716	332	8.97	0.6			8.1			1.2		
0732	299	8.08	0.3	10.6	17.1						
0752	233	6.30	0.9								

(Continued)

13.9.79									
MINE COORDINATES 4000S 5000E									
Time	Radon in Air (cont. radon monitor)		Wind Speed	Soil Temperature (°)		WL x10^{-3}	Wind Condition	
	mBq L^{-1}	pCi L^{-1}	(m s^{-1} (a)	-5cm	-15cm		Speed (m s^{-1}) (b)	Direction (°)
0812	100	2.71	2.2					
0832	100	2.71	3.5			3.6		
0852	67	1.82	3.4			3.9		
0912	33	0.89	3.4			0.1		
0932	67	1.82	3.3	16.0	17.0	0.5		
0952	67	1.82	3.3					
1012	33	0.89	3.4			0.2		
1032	67	1.82	3.1					
1052	0	0.00	3.4					
1112	33	0.89	3.5	27.0	17.4	0.4		
1132	33	0.89	3.3	28.0	17.5	0.4		
1152	67	1.82	3.6			0.5		
1212	33	0.89	3.3					
1232	67	1.82	3.4					
1252	0	0.00	3.6			0.3		
1312	67	1.82	3.4	33.8	18.4	0.1		
1332	0	0.00	3.7	35.0	18.6	0.4		
1352	67	1.82	3.7					
1412	67	1.82	3.2	35.5	19.0	0.4		
1432	33	0.89	2.9					
1452	33	0.89	2.8	35.5	19.5	0.1		
1512	33	0.89	3.1					
1532	0	0.00	2.9	34.0	20.0	0.1		
1552	0	0.00	3.5					
1612	67	1.82	3.1	32.8	20.2	0.1		
1632	33	0.89	3.3					
1652	0	0.00	3.0	31.8	20.4			
1712	0	0.00	2.8					

(Continued)

13.9.79								
MINE COORDINATES 4000S 5000E								
Time	Radon in Air (cont. radon monitor)		Wind Speed	Soil Temperature (°)		WL $X10^{-3}$	Wind Condition	
	$mBq\ L^{-1}$	$pCi\ L^{-1}$	$(m\ s^{-1})$ (a)	-5cm	-15cm		Speed $(m\ s^{-1})$ (b)	Direction (°)
1732	67	1.82	2.4					
1752	0	0.00	2.0					
1812	67	1.82	1.4					
1832	33	0.89	1.3					
1852	33	0.89	1.1					
1912	33	0.89	1.1					
1932	33	0.89	1.3			0.1		
1952	67	1.82	1.3			0.3		
2012	67	1.82	1.0					
2032	33	0.89	1.3			0.9		
2052	67	1.82	1.7			1.2		
2112	33	0.89	1.5	19.0	20.7	1.4		
2132	100	2.71	1.4					
2152	67	1.82	1.5	19.0	20.5	1.1		
2212	67	1.82	1.6	18.5	20.3	1.4		
2232	33	0.89	1.8			0.8		
2252	67	1.82	1.5			0.7		
2312	67	1.82	1.5			0.7		
2332	33	0.89	1.2	18.0	20.0	0.7		
2352	33	0.89	0.9	17.5	20.0	0.7		

(Continued)

14.9.79											
MINE COORDINATES 4000S 5000E									MINE COORDINATES 8000N 23200E		
Time	Radon in Air (cont. radon monitor)		Wind Speed	Soil Temperature (°)		WL $x10^{-3}$	Wind Condition		WL $x10^{-3}$	Wind Condition	
	mBq L^{-1}	pCi L^{-1}	($m\ s^{-1}$) (a)	-5cm	-15cm		Speed ($m\ s^{-1}$) (b)	Direction (°)		Speed ($m\ s^{-1}$) (b)	Direction (°)
0016	67	1.82	0.6								
0036	100	2.71	0.3								
0056	67	1.82	0.4								
0116	133	3.60	0.6			1.1					
0136	100	2.71	0.6			0.8					
0156	100	2.71	0.5	14.9	19.5	0.9					
0216	100	2.71	0.8			0.2	0.3	0			
0236	100	2.71	0.7	14.8	19.5	0.2					
0256	133	3.60	0.5	14.6	19.3	0.2			1.5	0.7	337
0316	133	3.60	0.5			1.2			1.2		
0336	100	2.71	0.7	14.6	19.2	1.9			1.7		
0356	67	1.82	0.7	14.6	19.1	1.4			1.4		
0416	67	1.82	0.8			1.3	0.3	0	2.1		
0436	100	2.71	1.0	14.2	19.0	1.7			2.5		
0456	100	2.71	1.2	13.8	18.9	3.6	0.5	315	1.7		
0516	100	2.71	1.1			1.6			2.8		
0536	100	2.71	0.8	13.5	18.8	2.2			2.0		
0545	Radon in Air (spot samples)								67 mBq L^{-1} (1.8 pCi L^{-1})		
0556	133	3.60	0.9	13.2	18.6	2.4			2.4	0.3	337
0605	Radon in Air (spot samples)								113 mBq L^{-1} (3.0 pCi L^{-1})		
0616	133	3.60	1.4			2.5			1.9		
0636	100	2.71	2.3	13.1	18.5	2.4	0.8	337	2.2		
0656	67	1.82	2.6	13.3	18.5	1.2			2.1		
0716	133	3.60	2.9								
0736	100	2.71		13.9	18.4						
0756	33	0.89									
0816	67	1.82									
0836	100	2.71									

(Continued)

14.9.79									
MINE COORDINATES 4000S 5000E									
Time	Radon in Air (cont. radon monitor)		Wind Speed	Soil Temperature (°)		WL $\times 10^{-3}$	Wind Condition		
	mBq L^{-1}	pCi L^{-1}	(m s^{-1}) (a)	-5cm	-15cm		Speed (m s^{-1}) (b)	Direction (°)	
0856	33	0.89							
0916	100	2.71							
0936	33	0.89							
0956	67	1.82							
1016	33	0.89							
1036	0	0.00							
1056	67	1.82							
1116	33	0.89							
1136	0	0.00							
1156	33	0.89							

(Continued)

15.9.79											
MINE COORDINATES 4000S 5000E									MINE COORDINATES (Millbillillie Homestead) 28000N 13250E		
Time	Radon in Air (cont. radon monitor)		Wind Speed	Soil Temperature (°)		WL $x10^{-3}$	Wind Condition		WL $x10^{-3}$	Wind Condition	
	$mBq\ L^{-1}$	$pCi\ L^{-1}$	$(m\ s^{-1})$ (a)	-5cm	-15cm		Speed $(m\ s^{-1})$ (b)	Direction (°)		Speed $(m\ s^{-1})$ (b)	Direction (°)
0049						1.1			0.6		
0109						1.1			0.6		
0130				19.2	20.7	1.2			0.6		
0150						1.2			0.7		
0210				19.2	20.7	1.4	0.2	45	0.6		
0220						1.3			0.5		
0240				18.9	20.6	1.8			0.5		
0300				18.9	20.6	2.6	0.3	315	0.5		
0322				18.5	20.5	3.3	0.0		1.0		
0342						2.5			0.6		
0404				18.4	20.4	1.6	0.3	45	1.2		
0428				18.3	20.4	0.4	[illegible]	270	1.2		
0448						0.4			1.2		
0510				18.3	20.3	0.3	1.6	270	0.6		
0530						0.2	2.8	270	0.4		
0550						0.2			0.4		

TABLE 2

AVERAGE RADON AND RADON DAUGHTER CONCENTRATIONS IN AIR

(over a ten-day period - 5.9.79 - 15.9.79)

Locations	Sampling Periods (h)	Average Radon Concentration in Air $mBq\ L^{-1}$ ($pCi\ L^{-1}$)		Average Working Level $\times 10^{-3}$	
		Continuous Radon Monitor	Passive Dosimeter	Rolle Method	CEA-Steppe Monitor
4000S 5000E	0000-0800	180 (4.86)		16.89	
	0800-1700	45 (1.21)		1.55	
	1700-2400	97 (2.62)		5.74	
	0000-2400	101 (2.73)	101 (Calibration point)	7.08	6.7
4250N 3500E	0000-2400		75 (2.02)		1.4
250S 14500E	0000-2400		101 (2.73)		2.6

TABLE 3a

RADON EMANATION AND GAMMA DOSE RATES

Location (Mine area)		Distance from 4000S 5000E	Emanation Rate		Surface Gamma Dose Rate
(Mine Coordinates)		(km)	$Bq\ m^{-2}\ s^{-1}$	$fCi\ cm^{-2}\ s^{-1}$	$\mu rad\ h^{-1}$
4000N	5000E	2.438	0.07±0.007	0.18±0.02	8
3000N	5000E	2.134	0.08±0.007	0.22±0.02	8
2000N	5000E	1.829	0.06±0.007	0.16±0.02	8
1000N	5000E	1.524	0.22±0.01	0.59±0.03	8
0000	5000E	1.219	0.13±0.007	0.36±0.02	8
1000S	5000E	0.914	0.08±0.007	0.22±0.02	8
2000S	5000E	0.610	0.05±0.02	0.13±0.06	8
			0.04±0.004	0.10±0.01	
3000S	5000E	0.305	0.07±0.01	0.19±0.03	8
4000S	5000E	0	0.10±0.02	0.27±0.05	9
			0.09±0.007	0.23±0.02	
5000S	5000E	0.305	0.14±0.03	0.39±0.07	9
6000S	5000E	0.610	0.33±0.06	0.88±0.15	16
7000S	5000E	0.914	0.06±0.007	0.17±0.02	20
7500S	5000E	1.067	0.11±0.04	0.30±0.10	20
8000S	5000E	1.219	0.06±0.03	0.16±0.08	20
8500S	5000E	1.372	1.43±0.06	3.87±0.15	38
			1.25±0.06	3.39±0.15	
9000S	5000E	1.524	0.14±0.02	0.39±0.05	28
9500S	5000E	1.676	0.03±0.01	0.07±0.03	20
11300S	5000E	2.800	0.20±0.03	0.53±0.07	8
			0.11±0.03	0.31±0.09	
7000S	5500E	0.927	0.22±0.03	0.59±0.08	28
7000S	5750E	0.943	0.16±0.06	0.42±0.15	55
7000S	7000E	1.099	0.04±0.05	0.10±0.13	60
7000S	8750E	1.464	1.85±0.13	5.00±0.35	45
7000S	9000E	1.524	1.13±0.11	3.06±0.30	100
7250S	5500E	1.002	0.00±0.04	0.00±0.10	55
7250S	6000E	1.036	0.09±0.03	0.25±0.08	100
7500S	4250E	1.991	0.08±0.03	0.22±0.07	180
7500S	9000E	2.167	0.17±0.04	0.45±0.12	50

TABLE 3b

RADON EMANATION AND GAMMA DOSE RATES

Location (Regional Area)	Distance from 4000S 5000E	Emanation Rate		Surface Gamma Dose Rate
(Mine Coordinates)	(km)	Bq m^{-2} s^{-1}	fCi cm^{-2} s^{-1}	μrad h^{-1}
250S 14500E	3.172	0.04±0.03	0.12±0.08	8
5000S 17000E	3.672	0.04±0.02	0.12±0.06	8
14000N 15000E	6.276	0.07±0.007	0.18±0.02	8
14000N 14990E		0.10±0.004	0.28±0.01	8
14000N 5010E	5.486	0.06±0.007	0.15±0.02	8
14000N 5000E		0.04±0.007	0.11±0.02	9
Site X	10.4	0.02±0.005	0.045±0.01	8
Sandhill Well	10.5	0.03±0.005	0.07±0.01	8
(Site Y)		0.03±0.007	0.085±0.02	8
		0.04±0.01	0.10±0.03	
Hadji Well	9.6	0.009±0.004	0.02±0.01	8
		0.04±0.007	0.10±0.02	
Homestead	9.5	0.03±0.02	0.08±0.05	8
		0.07±0.01	0.20±0.04	8

TABLE 4

AVERAGE AND TOTAL EMANATION RATES

OF RADON FROM THE SURFACE

Zone	Distance from 4000S 5000E (km)	Area km^2	Average Emanation Rate Bq m^{-2} s^{-1} (fCi cm^{-2} s^{-1})		Total Emanation kBq s^{-1} (μCi s^{-1})	
Inner Mine	0-2	3.1	0.30	(0.82)	930	(25)
Outer Mine	2-3	3.9	0.126	(0.32)	460	(11)
Regional	> 3		0.044	(0.12)	44 (1.2) per km^2	

TABLE 5

RADON CONCENTRATION IN WATER

(Measurements were made by two methods (A) and (B) ; see Section 2:4)

Regional Sites	Radon Concentration Bq L^{-1} (nCi L^{-1}) Method B	Mine Sites	Radon Concentration Bq L^{-1} (nCi L^{-1}) Method A	Method B
Town Supply:		4000N 4500E		201±16 (5.4±0.4)
Stand Pipe	22±2 (0.6±0.05)	2000N 5000E		29±13 (0.8±0.4)
Well 1	6±1.5 (0.2±0.04)	1000S 5000E		310±20 (8.4±0.5)
Well 2	11.5±1.6 (0.3±0.04)	1750S 5000E		372±22 (10.1±0.6)
		2250S 5000E		871±26 (23.6±0.7)
Baldy Well	34±2.5 (0.9±0.07)	3000S 5000E		669±22 (18.1±0.6)
	28±2.5 (0.8±0.07)	4000S 0000	1028±26 (27.8±0.7)	1185±34 (32.0±0.9)
		4000S 3750E	1478±37 (40.0±1.0)	524±26 (14.2±0.7)
Mission Bore:		4000S 5750E		524±131 (14.2±3.5)
Non production	0±1 (0±0.03)	4000S 6500E		210±16 (5.7±0.4)
Production	50±2.6 (1.4±0.07)	4000S 7000E		802±26 (21.7±0.7)
	41±2.6 (1.1±0.07)	4000S 8000E	4706±118 (127.2±3.2)	3602±50 (97.3±1.3)
		4000S 9000E		1343±36 (36.3±1.0)
Millbillillie Homestead:		4000S 9500E		3703±55 (100.1±1.5)
		7000S 5500E		1202±33 (32.5±0.9)
Bore	81±8 (2.2±0.2)	7000S 5750E		1586±39 (42.9±1.1)
Tank	25±5 (0.7±0.1)	7000S 7000E	2337±58 (63.2±1.6	2736±49 (73.9±1.3)
		7000S 8750E		2241±46 (60.6±1.2)
		7000S 9000E	978±24 (26.4±0.7)	1748±39 (47.2±1.1)

TABLE 5 (contd.)

Regional Sites	Radon Concentration Bq L^{-1} (nCi L^{-1}) Method B	Mine Sites	Radon Concentration Bq L^{-1} (nCi L^{-1}) Method A	Method B
Salt Well	3017±38 (81.6±1.0)	7250S 5500E	4644±116 (125.5±3.1)	3853±56 (104.2±1.5)
Uramurdah Well	138±10 (3.7±0.3)	7250S 6000E		1166±17 (31.5±0.5)
Sandhill Well		7500S 4250E		801±15 (21.7±0.4)
(Site Y)	294±14 (7.9±0.4)	7500S 9000E	2085±52 (56.3±1.4)	2084±52 (56.3±1.4)
		8500S 5000E	9488±237 (256.4±6.4)	7488±14 (202.4±0.4)
14000N 18500E	691±22 (18.7±0.6)			
Twin Mills	16± 6 (0.4±0.15)			
Hadji Well	7± 5 (0.2±0.1)			

TABLE 6a

RADON EMANATION RATE, RADON IN WATER, SURFACE GAMMA EMISSION AND URANIUM MINERALISATION AT VARIOUS SITES

Location	Mineralisation		Radon Emanation		Radon in Water		Surface Gamma Emission	
	Description	Level*	Value $Bq\ m^{-2}s^{-1}$	Level	Value $Bq\ L^{-1}$	Level	Scintillometer Reading counts min^{-1}	Level
7000S 5750E	Ore at 0.3-1.3 m	H	0.16	M	1586	M	8000	H
7000S 7000E	Ore at 0.3-1.3 m	H	0.04	L	2736	H	10000	H
7000S 8750E	Ore at 0.7-1.5 m	H	1.85	H	2241	H	6000	M
7000S 9000E	No ore	L	1.13	H	1748	H	20000	H
7250S 5500E	No ore	L	0.00	L	3853	H	8000	H
7250S 6000E	Ore at 2.5-3.5 m	M	0.09	L	1166	M	20000	H
7500S 4250E	Low grade ore 0.5-1.5 m	M	0.08	L	801	M	25000	H
7500S 9000E	Ore at 0.2-1.2 m	H	0.17	M	2084	H	7000	M

* LEVEL CLASSIFICATION

	Mineralisation	Radon Emanation	Radon in Water	Surface Gamma Emission
H	Ore at < 1 m	> 0.74	> 1600	> 7000
M	Ore at > 1 m	0.12 to 0.74	100 to 1600	1000 to 7000
L	No ore	< 0.12	< 100	< 1000

TABLE 6b

CORRELATIONS BETWEEN HIGH VALUES OF A PARTICULAR PARAMETER AND GIVEN LEVELS OF THE OTHER PARAMETERS

	Mineralisation		Radon Emanation		Radon in Water		Surface Gamma Emission	
	LL	H%	LL	H%	LL	H%	LL	H%
Mineralisation	-		L	50%	L	60%	L	33%
Radon Emanation	L	25%	-		L	40%	L	17%
Radon in Water	M	75%	H	100%	-		M	50%
Gamma Emission	M	50%	M	50%	M	60%	-	

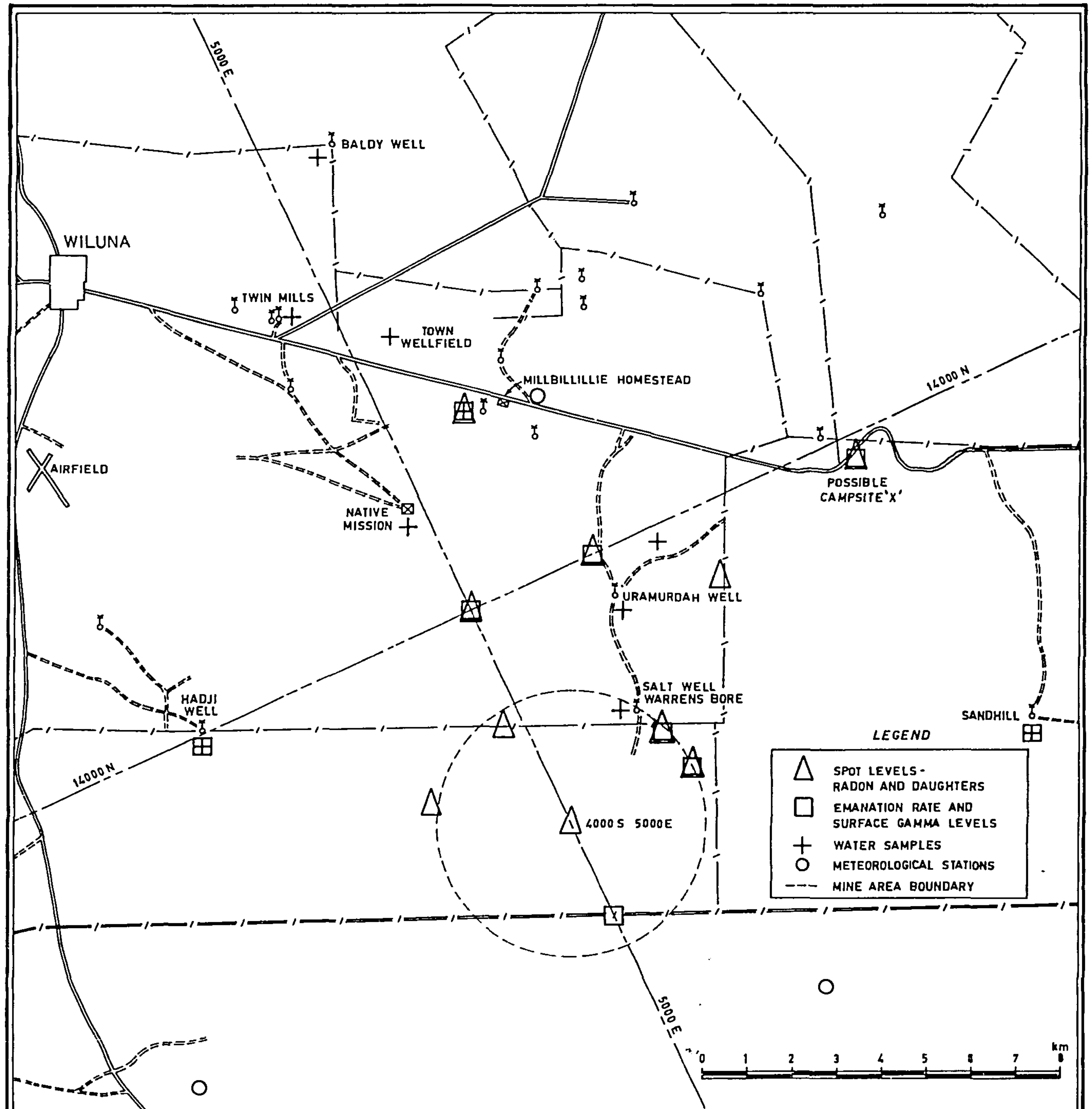
LL = Lowest level of one of the other parameters associated with a high level of the particular parameter

H% = The number of times (as a percentage) that the value of a parameter associated with a high value of the particular parameter is itself high

TABLE 7

RADON EMANATION FROM LAKE WAY ORE

Sample No.	Moisture Content (%)	Uranium (%U)	Radium (Bq g^{-1})	Emanating Power (Bq g^{-1})	Emanating Coefficient
18292	0.57	0.0525	7.3	0.66 ± 0.05	0.09
18293	4.20	0.0420	5.9	0.65 ± 0.08	0.11
18294	4.03	0.0397	6.1	1.05 ± 0.1	0.17
18295	4.51	0.158	23	1.0 ± 0.1	0.04
18296	4.66	0.121	17	1.0 ± 0.1	0.06
18297	2.67	0.0619	8.1	0.65 ± 0.06	0.08
18298	1.21	0.0581	7.8	0.62 ± 0.05	0.08
18299	0.53	0.0913	13	0.67 ± 0.05	0.05
18300	0.52	0.0608	7.7	0.39 ± 0.04	0.05
18301	1.95	0.0256	4.1	0.31 ± 0.03	0.08
18315	3.19	0.0186	2.2	0.12 ± 0.02	0.05
18316	3.48	0.037	4.7	0.38 ± 0.04	0.08


5000 E
BALDY WELL
WILUNA
TWIN MILLS
TOWN
WELLFIELD
MILLBILLILLIE HOMESTEAD
14000 N
AIRFIELD
POSSIBLE
CAMPSITE 'X'
NATIVE
MISSION
URAMURDAH WELL
HADJI
WELL
SALT WELL
WARRENS BORE
SANDHILL
14000 N
LEGEND
SPOT LEVELS -
RADON AND DAUGHTERS
EMANATION RATE AND
SURFACE GAMMA LEVELS
WATER SAMPLES
METEOROLOGICAL STATIONS
MINE AREA BOUNDARY
4000 S 5000 E
5000 E
km
0 1 2 3 4 5 6 7 8

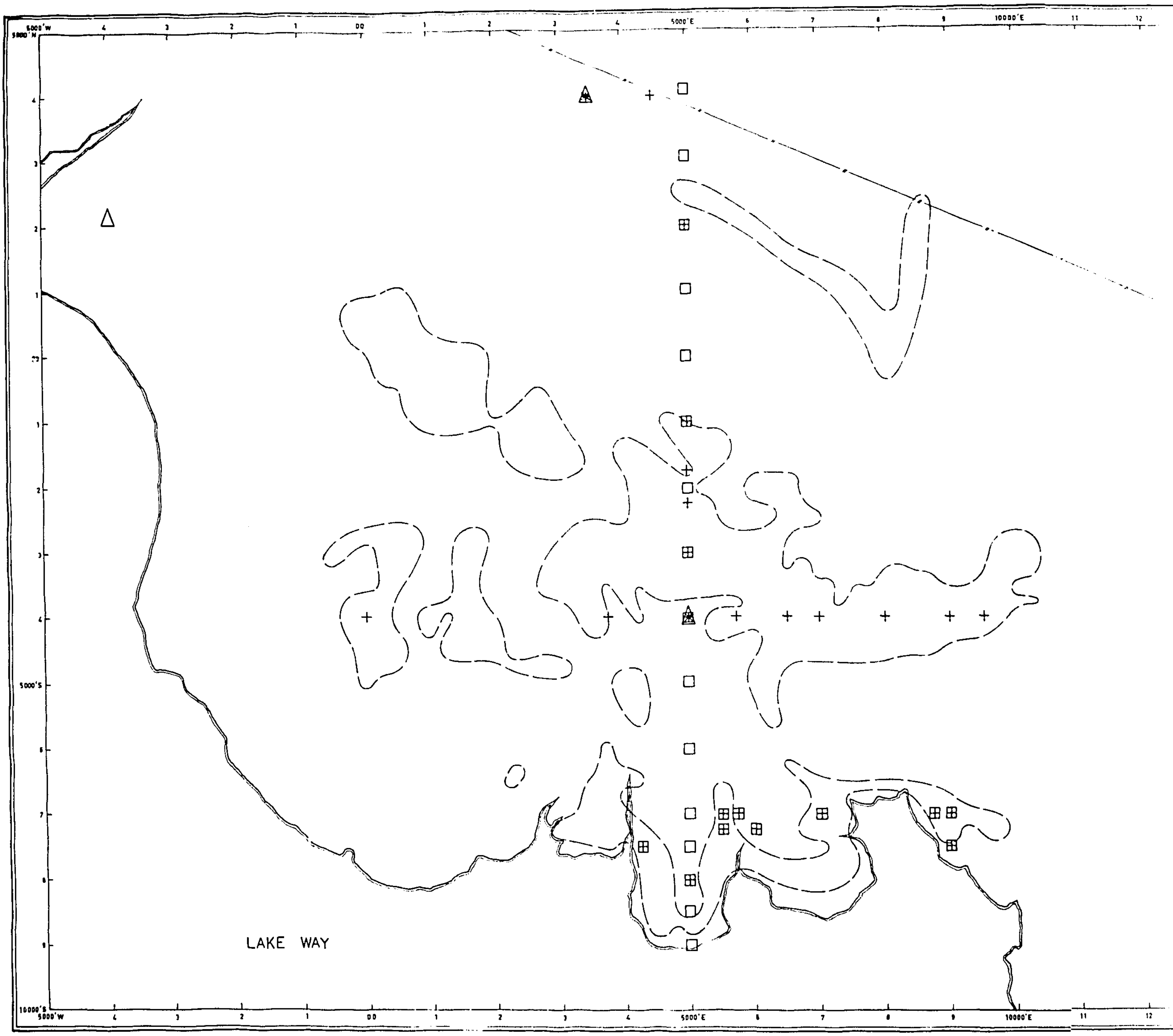
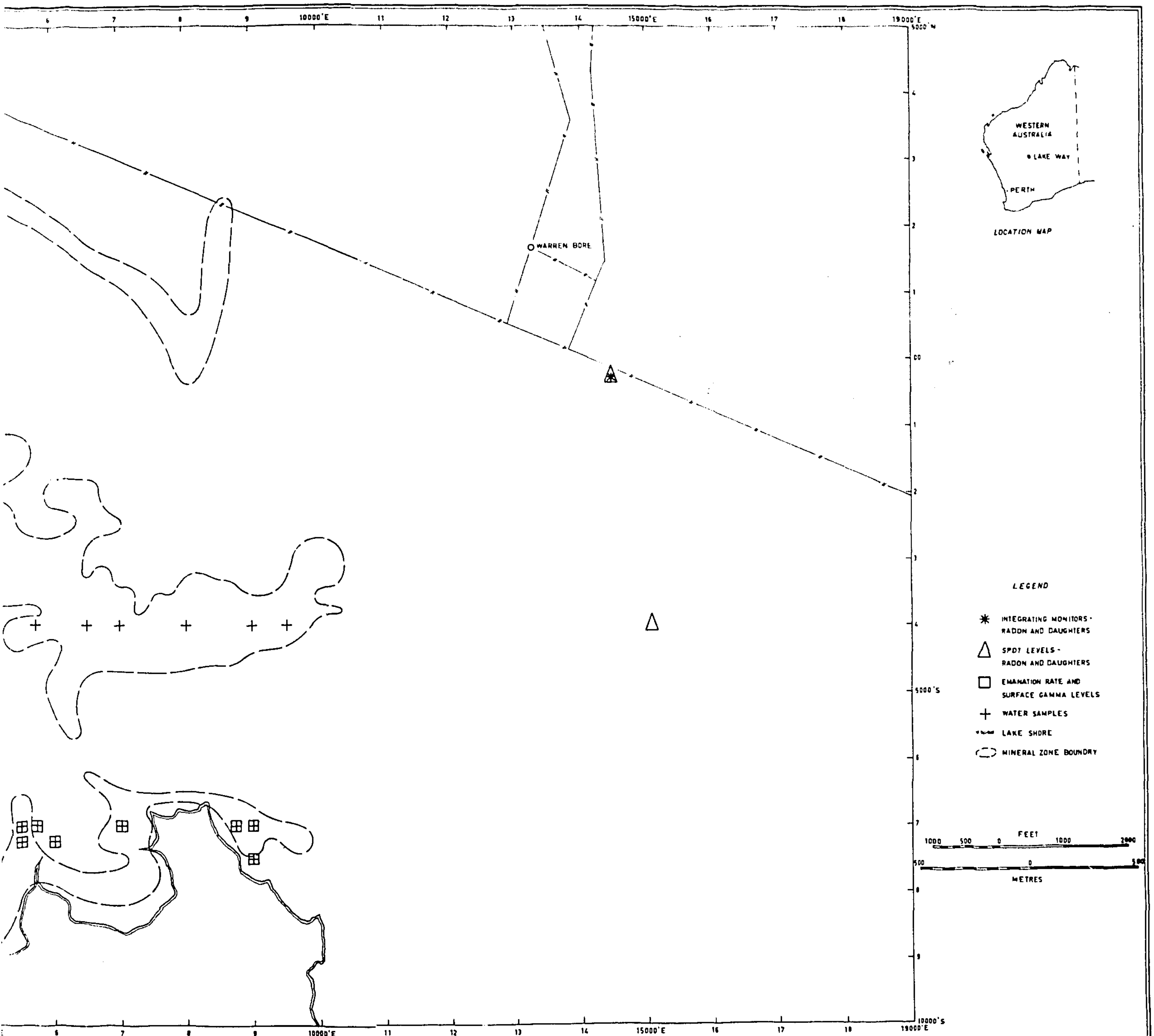


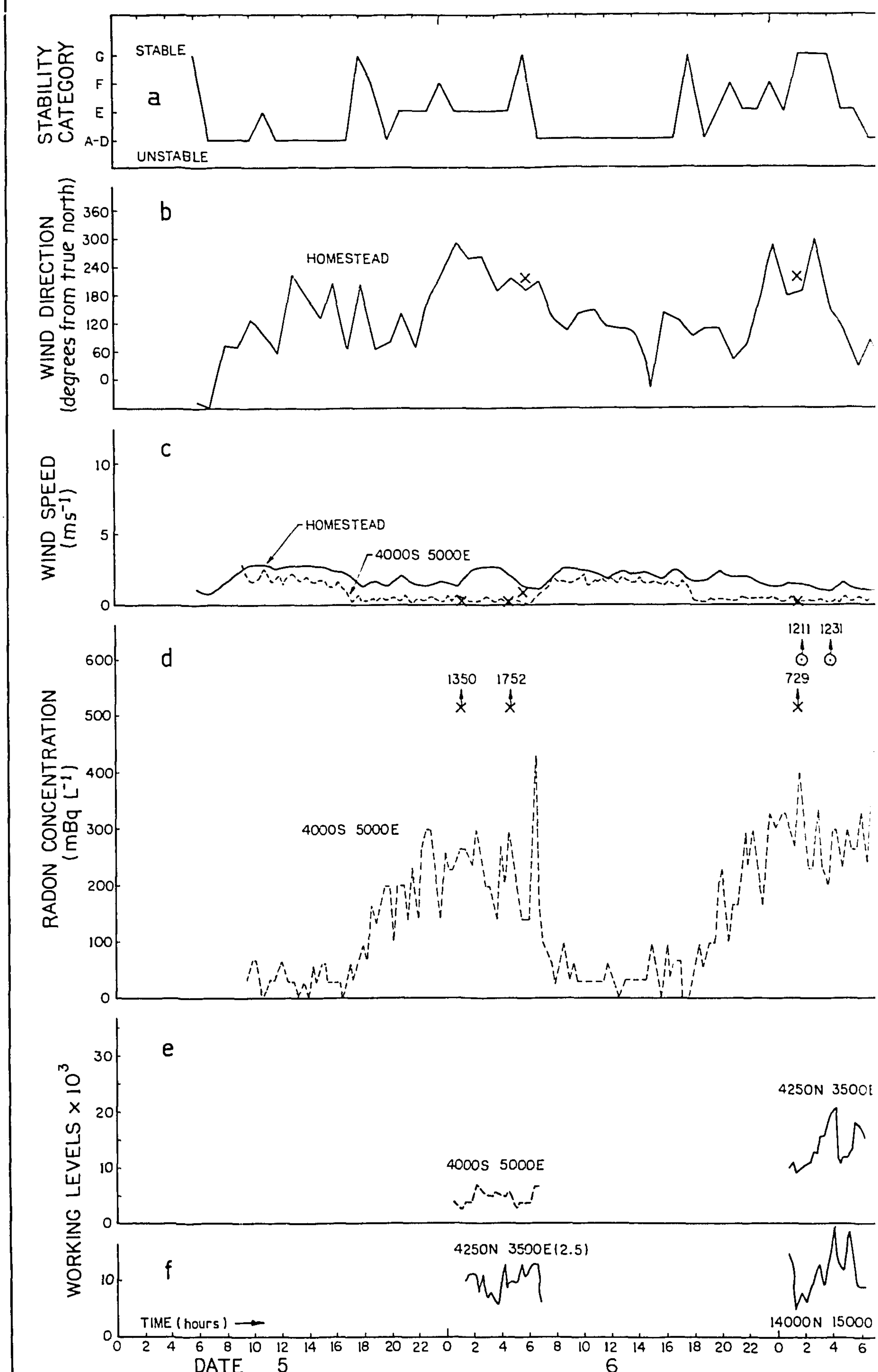
FIGURE 2. MAP OF MINE SITE SHOWING MEASUREMENT L

SECTION 1



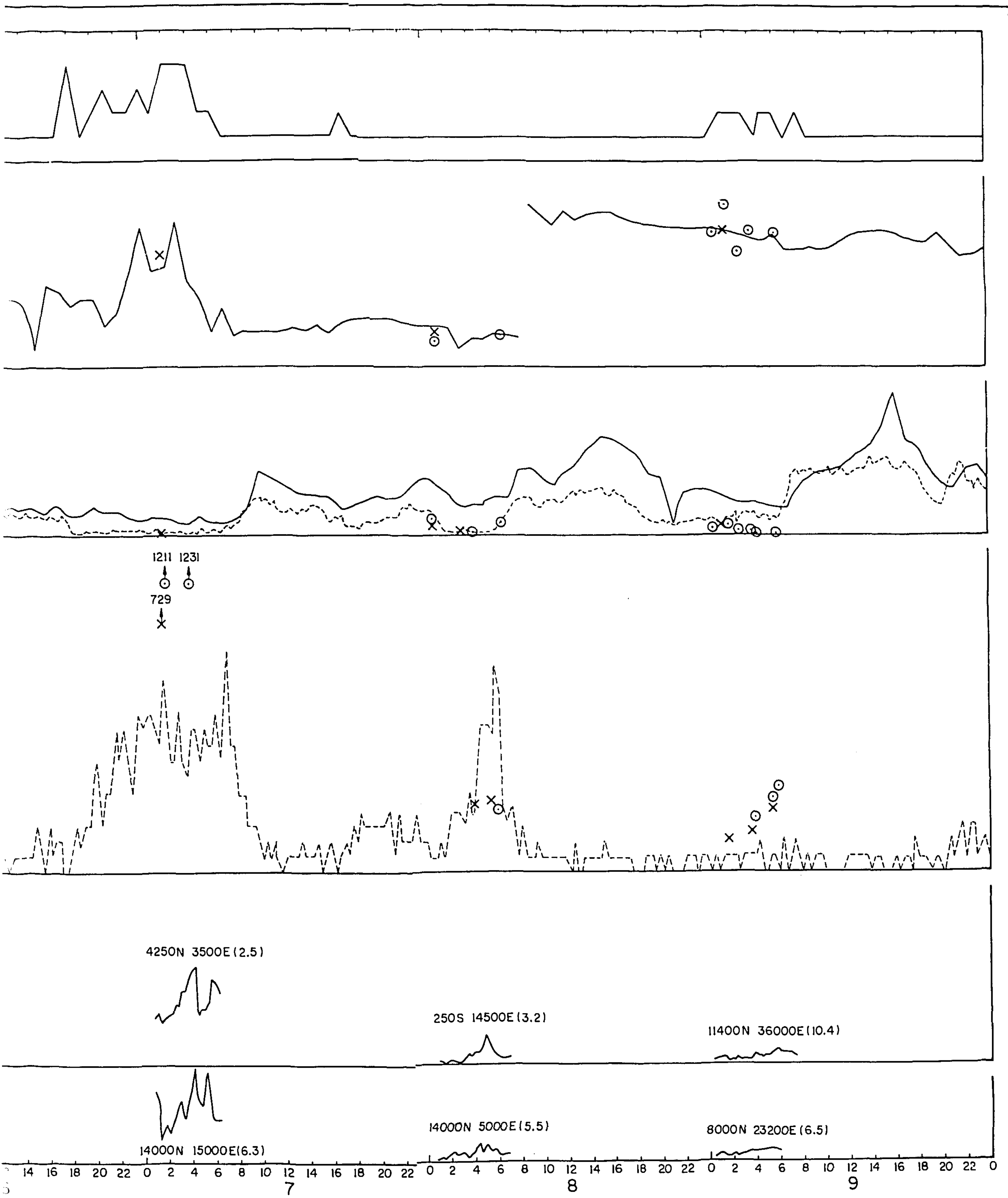
ΛINE SITE SHOWING MEASUREMENT LOCATION

SECTION 2



LEGEND

FIGURE 3. RADON/RADON DAUGHTERS IN



ON DAUGHTERS IN AIR AND WIND CONDITIONS, 5 TO 9 SEPTEMBER 1979

SECTION 2

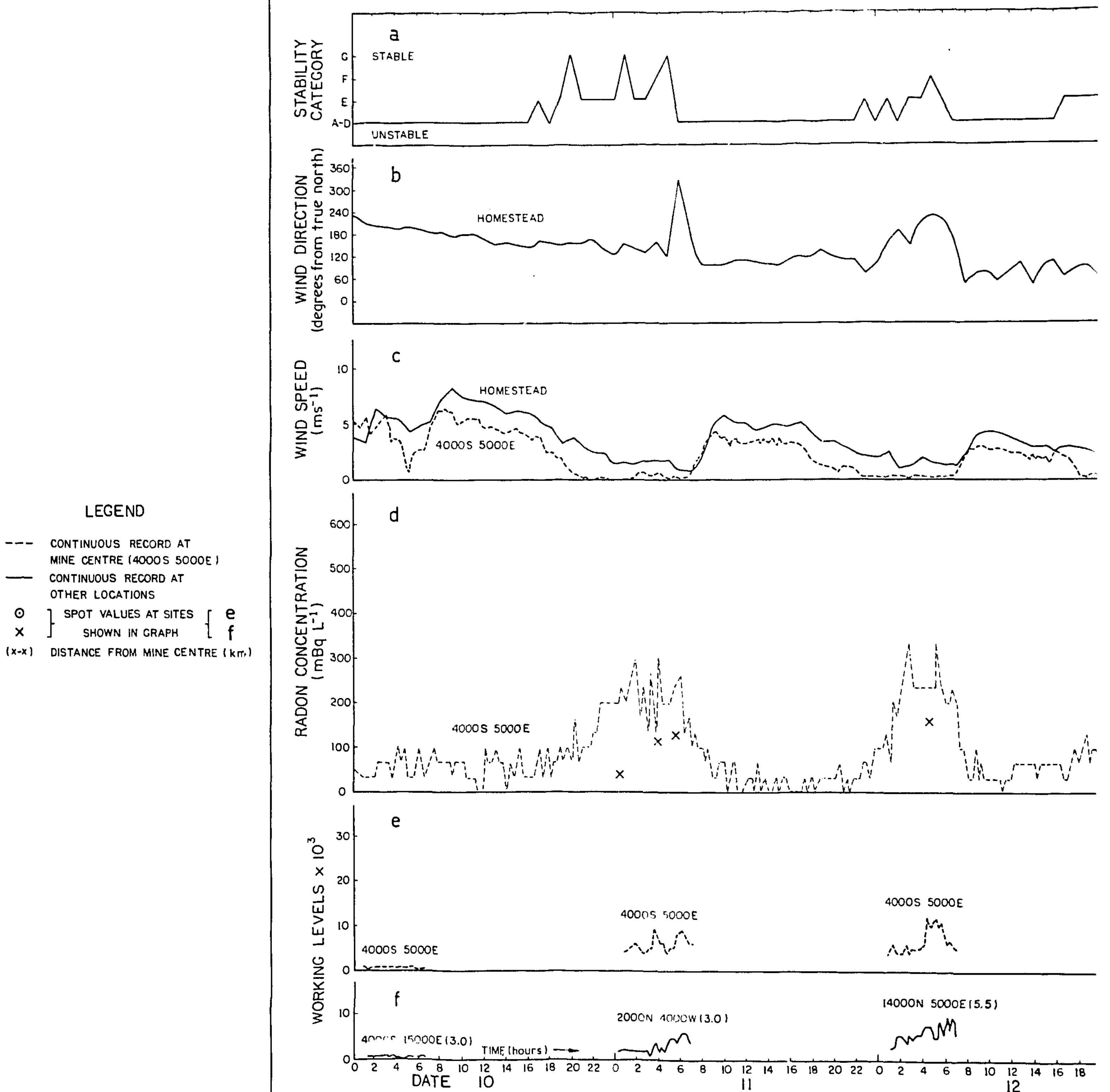
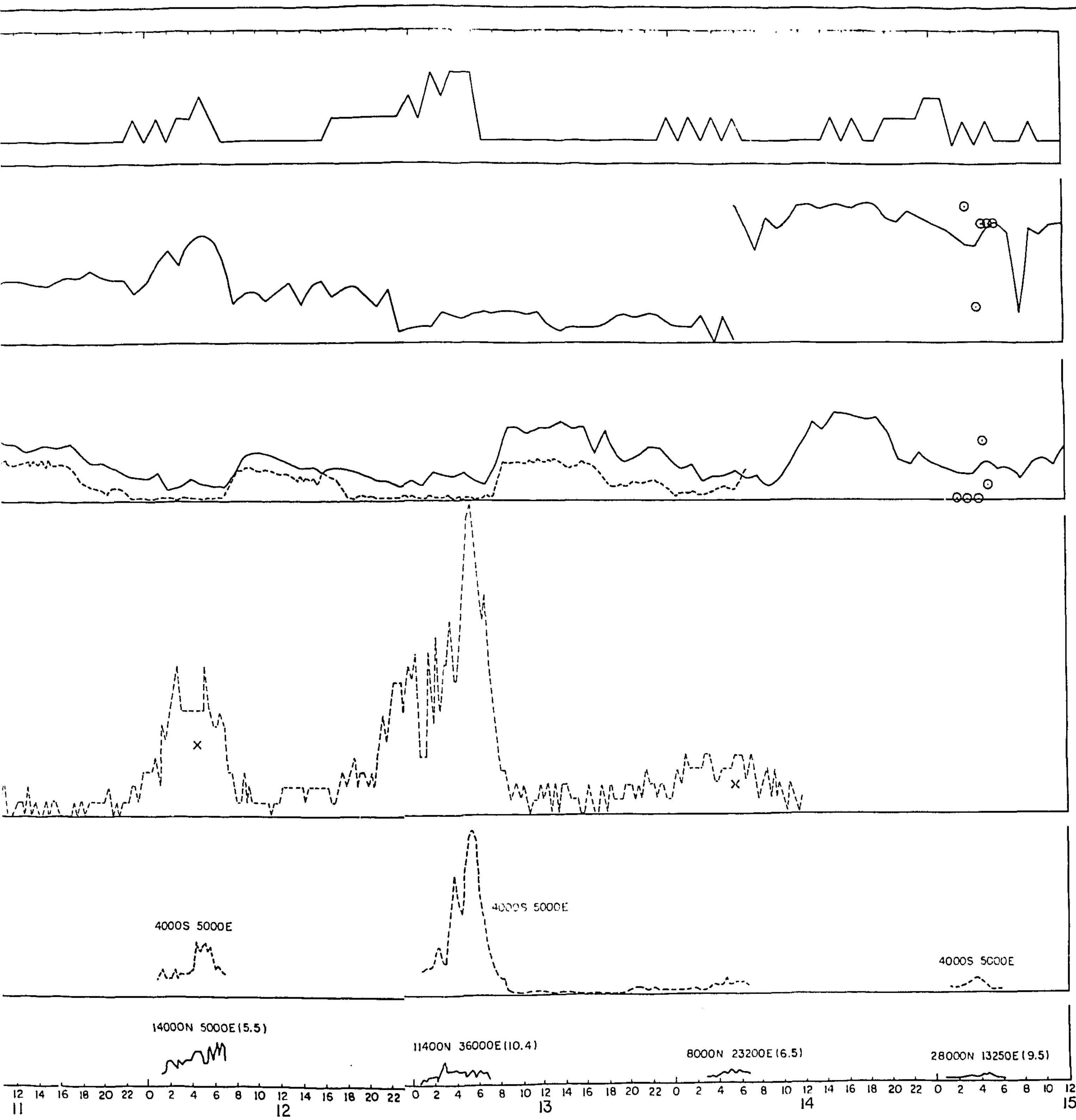


FIGURE 4. RADON/RADON DAUGHTERS IN AIR ANE

SECTION 1



ION DAUGHTERS IN AIR AND WIND CONDITIONS, 10 TO 15 SEPTEMBER 1979

SECTION 2

APPENDIX A
DERIVATION OF STABILITY CATEGORY

Atmospheric stability is a good index of the degree of mixing of air from different levels. In the case of radon, the concentration at ground level increases as the atmosphere becomes more stable. It is therefore of interest to find meteorological parameters which correlate strongly with atmospheric stability.

Two parameters are commonly used: the vertical temperature gradient at altitudes from 10 to about 100 m above ground level; and the standard deviation of the horizontal wind direction fluctuations over periods up to about an hour. In the present case, the temperature gradient can only be deduced from measurements at the four stations (Figure 1), which are separated by several kilometres. The errors resulting from such a deduction are likely to be large. On the advice of R.K. Steedman and Associates, the wind direction fluctuations have been selected as a more reliable indication of stability. The USAEC [1972] criteria for defining the Pasquill stability categories have been used; these are defined in Table A1.

TABLE A1

USAEC (1972) CRITERIA FOR DEFINING THE PASQUILL

STABILITY CATEGORIES

Stability Classification	Pasquill categories	σ_θ* (deg.)
Extremely unstable	A	25.0
Moderately unstable	B	20.0
Slightly unstable	C	15.0
Neutral	D	10.0
Slightly stable	E	5.0
Moderately stable	F	2.5
Extremely stable	G	1.7

* *standard deviation of horizontal wind direction fluctuation taken over a period of 15 minutes to 1 hour*

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