THE USE OF THE LONG-RANGE ALPHA DETECTOR (LRAD) FOR ALPHA EMISSION SURVEYS AT ACTIVE AND INACTIVE FIRING SITES

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ABSTRACT

Surveys were carried out at five different firing sites at Los Alamos National Laboratory to measure residual alpha emissions in earth contaminated with natural and depleted uranium. This contamination is caused by controlled experimental explosions during testing of the non-fissile components of nuclear weapons. Two conclusions were reached: the first is that post shot clearing of the experimental areas is effective at removing contamination and the second is that the diminution of alpha emissions due to aging is small.

INTRODUCTION

The technical area, TA-15 (Operable Unit 1086) at Los Alamos National Laboratory comprises 1200 acres of mesa tops, intersected and bounded by canyons, shown in Fig. 1. Since the 1940s this area has been used for the explosive testing of non-fissile components of nuclear weapons at locations called firing sites. Over the years, twelve such sites have been developed and two are currently in use. Many large explosive tests have taken place with the concomitant scattering of large amounts of natural or depleted uranium (the replacement for the fissile component) and to a lesser extent, beryllium and lead.

Recently there has been increasing concern over the build up of contaminants from these explosions in the surrounding areas, especially in the soil and the associated possible natural pathways for the spread of the contaminants. These concerns are driven by two different interests, the first being the safety of the workers at the active sites and the second being remediation so the mesa tops can eventually be made available for uses other than testing.

During the summer of 1993, five firing sites were surveyed for alpha emissions over a four week period by a two person crew. Fig. 1 shows a map of the major firing sites surveyed at TA-15. The sites chosen were the two active firing sites for health monitoring reasons and two of the inactive firing sites (the areas of the largest explosions) for the environmental restoration program. In addition a fifth site, not at TA-15, was monitored, which although officially prepared for uranium firing sites experiments, was mainly used for handling small amounts of high explosives.

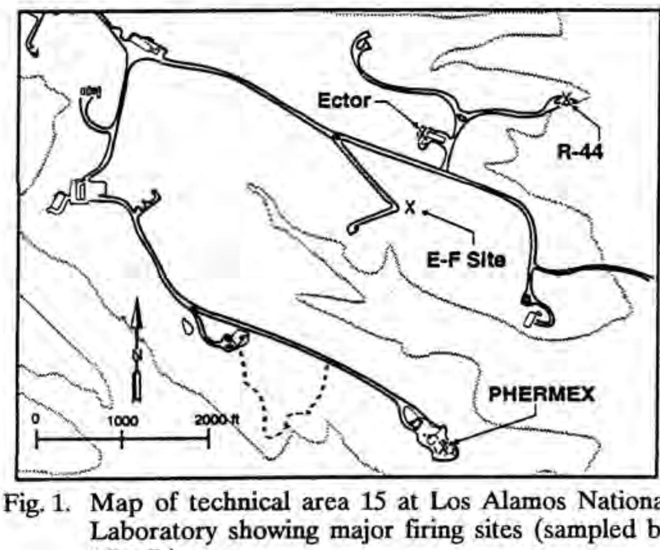

Fig. 1. Map of technical area 15 at Los Alamos National Laboratory showing major firing sites (sampled by LRAD).

The surveys were carried out using the Long-Range Alpha Detector (LRAD) (1) which monitors alpha emissions, in this case from the decay chains of uranium-238 and -235. The decay chains of concern are shown in Fig. 2.

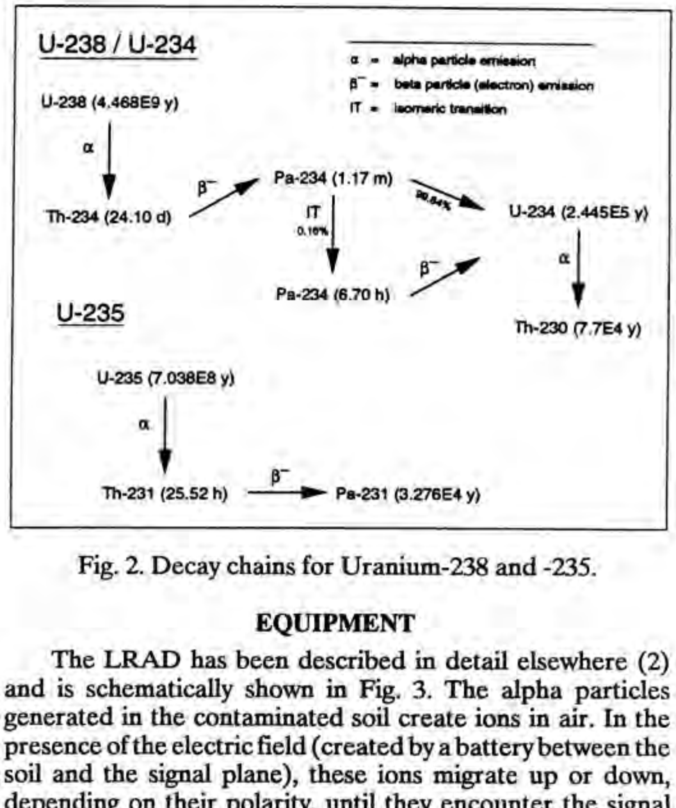

Fig. 2. Decay chains for Uranium-238 and -235.

EQUIPMENT

The LRAD has been described in detail elsewhere (2) and is schematically shown in Fig. 3. The alpha particles generated in the contaminated soil create ions in air. In the presence of the electric field (created by a battery between the soil and the signal plane), these ions migrate up or down, depending on their polarity, until they encounter the signal plane or the soil respectively. The ions cause a current to register on the electrometer, a DC current of a few femtoamps (10^{-15}A). This current reading can be converted directly to roentgen per unit time since the latter is defined in terms of rate of ion production in air. However alpha contamination has historically been described by activity rather than by exposure rate: DOE order 5400.5 states contamination limits in the more common form of disintegrations per minute/unit *area, dpm*/100cm^2. To convert to dpm/100cm^2 the background reading is subtracted from the measured current and multiplied by the conversion rate of 6dpm/fA to get total dpm. This conversion is precise for 5.10 MeV average alpha energy (that from plutonium-239) and very nearly the same for the alphas from the uranium decay chains (between 4.19 and 6.14 MeV). Converting these readings to ppm or pCi/g requires several assumptions such as the depth of soil penetration of the alphas as well as soil density, composition and homogeneity.

The detector is an open bottomed box that is placed face down on the soil to be monitored and is calibrated using a set of NIST (National Institutes of Standards and Technology) traceable alpha sources. It weights about 300 lbs. and is mounted on the front loader of a small tractor. The electronics are permanently running so the set up time consists of bringing the trailer to the test location. The response time for the detector is between eight and fifteen minutes per measurement. A weed-eater was used to clear the vegetation from the spot to be monitored. Vegetation interferes with measurements in two ways: a blade of grass can cause a short circuit between the signal plane and the soil, creating currents orders of magnitude greater than those due to alpha particles, and vegetation can shield the detector from the alpha-emitter activity beneath it. The advantages of this method for alpha detection include being fast, reliable and non intrusive. The major disadvantage is that it only measures the surface layer (36μm).

The instrument is currently being manufactured by Eberline Instruments Corporation (after development at Los Alamos National Lab.) and is also available in a hand held model.

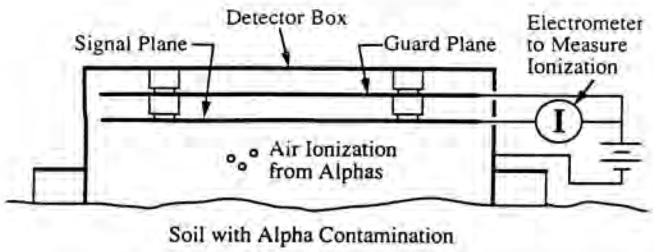

Fig. 3. LRAD soil surface monitor.

DISCUSSION OF FIRING SITE DATA

Experiments at all of the firing sites spread uranium (and other contaminants) radially from the explosive point except when physical barriers, such as berms and walls, intercepted the debris. The alpha emissions data collected were used to create the charts shown in Figs. 4-8.

Active Firing Sites

PHERMEX (Pulsed, High-Energy, Radiographic, Machine Emitting X-Rays)

For the past three decades, the PHERMEX facility has been used to examine the performance of weapon designs. In dynamic radiography, PHERMEX is used to produce extremely short duration bursts of x-rays. After passing through the test object during the explosion, the x-rays are recorded on film as an image of the test device at a preselected time. PHERMEX continues in operation although the amounts of uranium used now is less than 1000kg per year. In a previous radiological survey (3) in 1982 PHERMEX was estimated to have about one-seventh of the radioactive material found at E-F site (an inactive site discussed later). As at all firing sites, there are pieces of depleted uranium near the firing point. The data collected at PHERMEX is shown in Fig. 4.

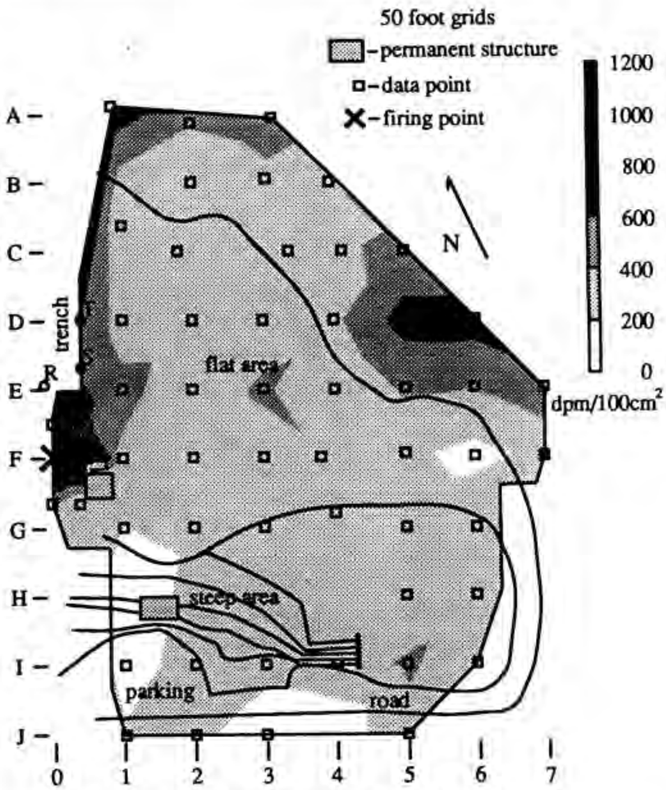

Fig. 4. LRAD monitoring at PHERMEX site.

The data shows lack of heavy contamination near the firing site. This is due to the extensive removal of contaminated soil after each shot, leaving the area adjacent to the firing point less contaminated than further away. There is one hot spot at PHERMEX where the detector saw very elevated readings, the level being about 10,000dpm/100cm^2 which coincides with the firing point. This point was not included in the interpolation of the data since the contamination is from a point source and not uniform soil distribution. There is contamination along the northern border of the monitored area where vegetation is present, showing the limits of post shot clearance. There is no clear radial distribution, due to the soil removal after the shots.

ECTOR

Ector has been used from the mid-1980s to the present time for dynamic radiography of explosion drive weapons components in a similar manner to PHERMEX but not as extensively. After larger tests, the dirt nearest the firing point is removed and "clean" soil fill is put in its place. This is done to keep the soil contamination levels around the firing point at or near background. The site is approximately 250 feet by 150 feet with terrain varying from flat with no vegetation near the firing point to broken with heavy vegetation around the western and southern perimeters. The data collected is shown in Fig. 5.

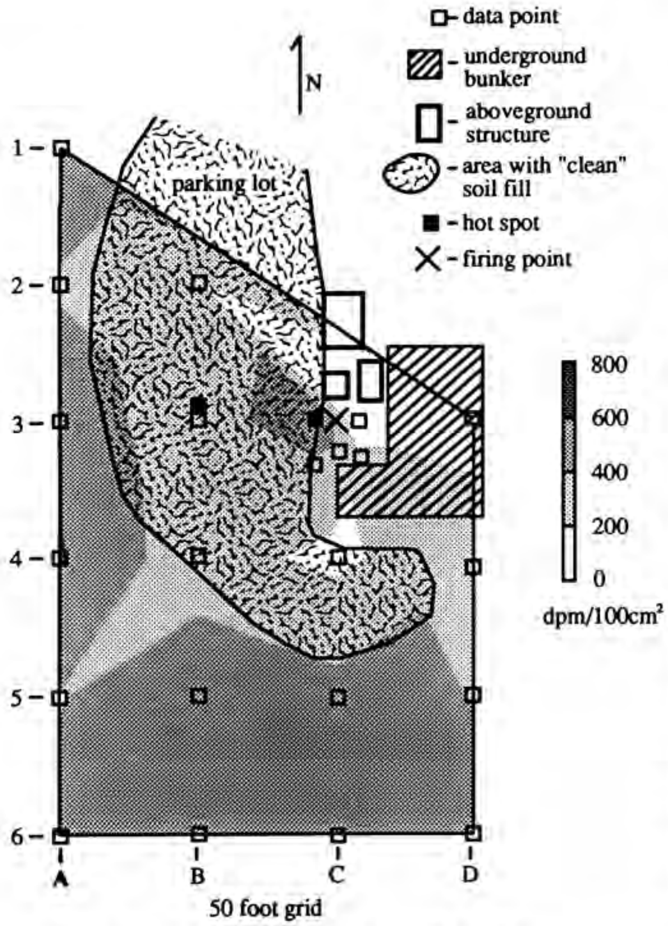

Fig. 5.LRAD monitoring at Ector Site.

As can be seen in Fig. 5, there are several spots which were considerably more contaminated than the surrounding soil. These isolated spots were not included in the interpolation because, if they were, unrealistically high levels of contamination would be found. As expected the imported soil is at or near background levels. The boundary between the indigenous and fresh soil was drawn before the data was collected but follows the edge of the hot zone well. Two hot spots were found; the one adjacent to the firing site gave a reading of $600 dpm/100 cm^2$ and the one due west of the firing site was caused by a lump of uranium embedded in the soil surface ($1150 dpm/100 cm^2$).

INACTIVE FIRING SITES

Firing Site E-F

Firing site E-F is now inactive but was the most extensively used firing site at Los Alamos, both in terms of length of active use (1947-1981) and the size of the individual explosions (up to 2500 lb). Initially, natural uranium was used but after 1957, was replaced by depleted uranium. In totality about 43,000 kg of natural uranium and 20,000 kg of depleted uranium were utilized here. Most of this uranium is thought to be still located in the soil since the main pathways for uranium to be removed (aerosolization and hydrologic runoff) are fairly minor. Because the sizes of the shots were so much bigger than at any other site, the size of the area potentially contaminated is much greater 800,0000 ft^2 and therefore a larger area was surveyed. The results are shown in Fig. 6.

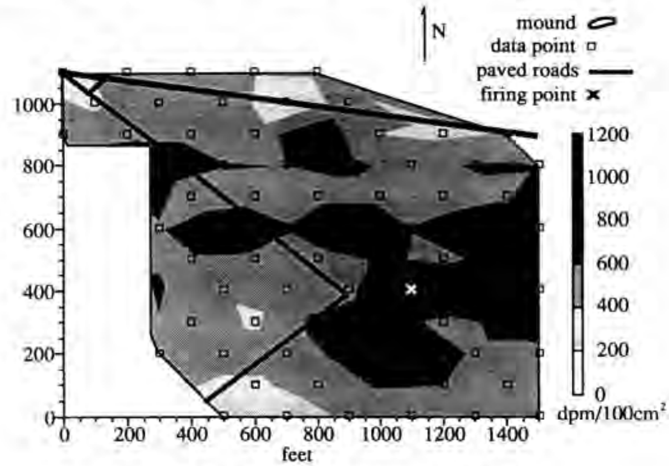

Fig. 6. LRAD monitoring at E-F site.

The results clearly show much higher activity than at the active sites, despite the time the area has been left to weather. Apparently there has been little migration of uranium, although the area to the northwest shows elevated uranium due to a shallow drainage ditch. The relative high and constant values are confirmed by soil samples taken from this drainage channel where the values of uranium concentration have been found to be 6495.4 ppm (s.d. = 2839.4) (4). The firing point has mounds of earth to the north and south resulting in lower contamination immediately to the north and south. Little contamination reaches the canyon edge to the south, due to the barrier mound between the edge and the firing point.

FIRING SITE R-44

The second inactive firing site to be surveyed is located at the area designated R-44. This firing site was built in 1951 and was used extensively from 1956 to 1978 for diagnostic tests for weapons components. Approximately 7000 kg of depleted uranium were consumed here. Since the two currently active sites were put into operation R-44 has only been used for small experiments. The area is approximately 600 ft from the canyon wall so after each shot the debris were pushed to the edge of the canyon and some fell down the canyon wall. It is considerably smaller than the E-F site (6000 ft^2 versus 800,000 ft^2). The data is shown in Fig. 7.

R-44 shows patterns more similar to Ector and PHERMEX than to E-F site, reflecting the smaller shots. The area immediately adjacent to the firing site has low alpha readings since the earth was pushed to the canyon edge and into the canyon. Yellow lumps of uranium (yellow cake) were seen on the surface but readings were not taken over them.

MINIMALLY USED FIRING SITE

TA-40, chamber 4

The area known as TA-40, Chamber 4 is a small blasting area, (7000 ft^2) designed to handle up to 25 lb of high explosive. There are reports of very limited uranium use in the distant past. The chamber is on an outcropping of a canyon wall, with the southern edge dropping off into the canyon. The

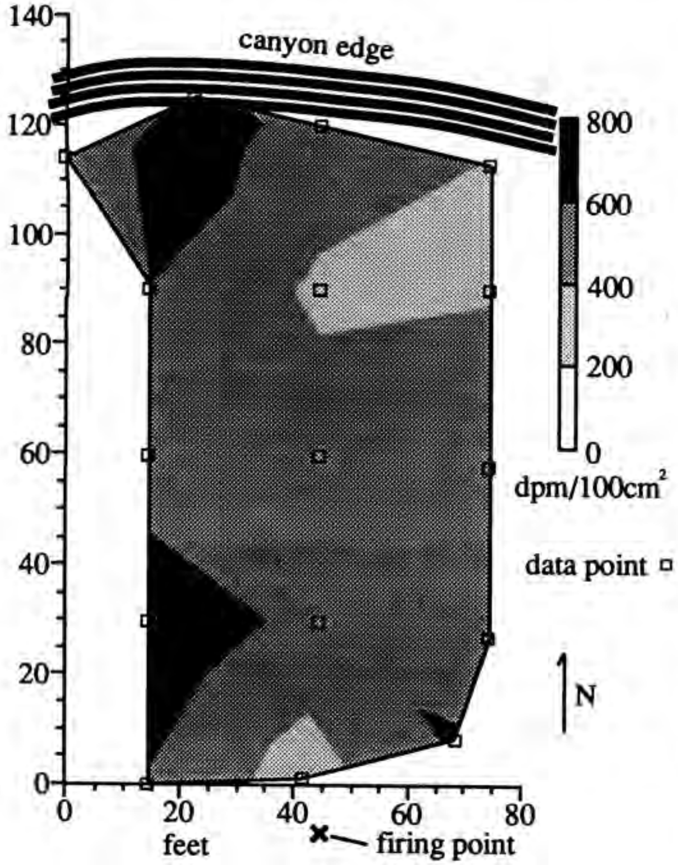

Fig. 7. LRAD monitoring at R-44.

soil is a sand/gravel mixture that does not appear to have been there before the existence of the site. The results are shown in Fig. 8.

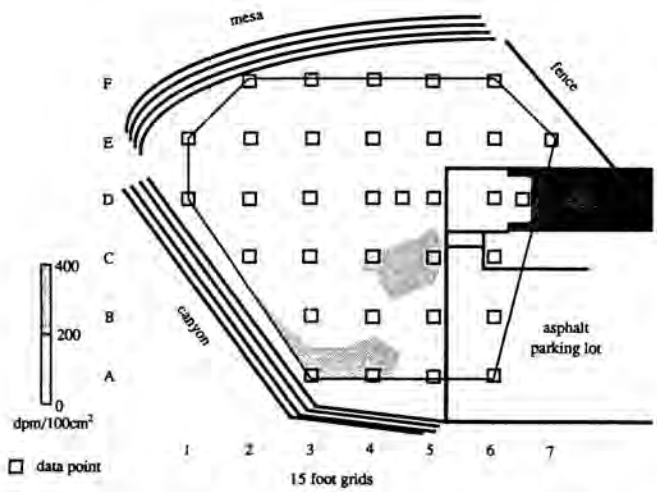

Fig. 8. LRAD monitoring at TA-40, chamber 4.

Chamber 4 although used for explosive tests has probably never been used with uranium with the possible exception of a few small shots many years ago. This is supported by the low contamination (at or below background of about 200dpm/100cm^2) measured at every data point at this site. The detector measured lower levels of alpha activity on asphalt than on the normal soil background, which is in keeping with results from other sites.

COMPARISON OF DATA

Comparison between the active and inactive sites shows clearly the effectiveness of post shot clearing. None of the sites show radial distribution of alpha activity due either to post shot clearing and/or weathering. At E-F the higher alpha levels in the northeast follow the drainage channels and show there is some hydrologic draining away of uranium. At the other sites the overall levels of contamination and the intermittent cleaning operations result in low activity and indistinguishable drainage pathways. All the sites exhibit "hot spots" due to large pieces of depleted uranium which may skew the calculation of the overall soil contamination.

CONCLUSIONS AND FUTURE DIRECTIONS

Examination of the data show low levels of contamination at all four sites and remarkably little effects of aging and weathering at the two inactive sites which have not been used for twenty years. Post-shot clearing of the experimental areas has been effective at removing alpha contamination sources.

In the summer of 1994, extensive soil sampling will be undertaken at E-F site and R-44 to further define the extent (both surface and subsurface) of contamination and to prepare for remediation.

ACKNOWLEDGEMENTS

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