POSTSHOT DISTRIBUTION AND MOVEMENT OF RADIONUCLIDES IN NUCLEAR CRATER EJECTA*

John J. Koranda, John R. Martin, Robert Wikkerink
and Marshall Stuart
Bio-Medical Division
Lawrence Radiation Laboratory, University of California
Livermore, California 94550

ABSTRACT

The distribution and postshot movement of radionuclides in nuclear crater ejecta are discussed in this report. Continuing studies of tritium movement in ejecta at SEDAN crater demonstrate that variations in tritium concentration are correlated with seasonal rainfall and soil water movements. Losses of 27 mCi H^3/ft^2 are evident on SEDAN crater lip at the end of a three year period of measurements in which an unusually large flux of rain was received.

The distribution of gamma emitting radionuclides and tritium is described in the recently created SCHOONER crater ejecta field. The specific activity of radionuclides in the SCHOONER ejecta continuum is shown for ejecta collected from the crater lip to 17 miles from GZ. The movement of W^{181} and tritium into the sub-ejecta preshot soil is described at a site 3000 feet from GZ.

INTRODUCTION

During a nuclear cratering event, the movement of earth from the detonation site to the surrounding landscape takes place in a relatively short time. Within a few seconds, millions of tons of ejecta or excavated earth materials may be thrown out of the crater area onto the surrounding topography (throwout) or put into the air to travel varying distances as airborne debris (fallout). A large fraction of the total ejecta falls back into the crater (fallback).

During the cratering process, radioactivity is present in the contained incandescent plasma within the mound of earth lifted by the detonation. As the mound breaks up and venting occurs, radionuclides in gaseous and condensed chemical states are released into the immediate atmosphere. Radioactivity is also injected into or permeates the earth mass moved by the detonation. The distribution and fate of the radionuclides produced in the detonation in various kinds of nuclear crater ejecta is the subject of this report.

*Work performed under the auspices of the U.S. Atomic Energy Commission.

METHODS

Ejecta samples are collected from the crater areas by two methods, depending upon the nature of the ejecta. At SEDAN crater, where ejecta is sandy, sample holes are dug with posthole augers fitted with 4 to 6 foot extension handles. Ejecta samples to depths of 8 feet are routinely taken from sampling sites around SEDAN crater by these methods. In the second method used at craters in hard rock media, where the ejecta is mainly crushed rock, the samples are obtained with shovel and trowel from the vertical wall of a large trench or from a sample pit. Samples are poured into polypropylene sample jars approximately 250 ml in volume and the lids are taped to prevent water loss. These samples are placed in 1000 ml vacuum flasks in the laboratory after the sample jar opening has been covered with #1 Whatman filter paper. The filter paper prevents blow-out of ejecta particles during the vacuum distillation of the interstitial water in the ejecta sample. Extraction of the interstitial water (capillary and hygroscopic water) from the sample usually takes 24 hours at which time only an extremely small amount of hygroscopic water remains. Tritium concentrations are determined by analyzing the extracted water by liquid scintillation counting.

Gamma radioactivity is determined by taking a 5-10 gram aliquot of the same sample from which tritium had been extracted, and placing it in a standard 20 ml counting vial. W^{181} activity is determined with a 3 inch NaI well crystal and a 2 channel pulse height analyzer, which has been calibrated to count W^{181} disintegrations between 50 and 60 KeV in a single channel. Other gamma emitting radionuclides are determined with a 12 cc germanium diode and a 4096 channel pulse height analyzer. Spectra are accumulated on magnetic tape from a disc memory with a computer program developed by Dr. Robert Heft and William Phillips, Bio-Medical Division, Lawrence Radiation Laboratory.

The number of nuclear cratering events one might study to obtain information on the distribution of radionuclides in nuclear crater ejecta is limited. The SEDAN detonation[1] of July 1962 was the first large scale nuclear cratering experiment that permitted long-term studies of an ejecta field. Radioecological studies conducted by the Bio-Medical Division, Lawrence Radiation Laboratory, have been in progress at SEDAN crater since 1965.[2-5] The CABRIOLET and BUGGY events, conducted early in 1968, were small nuclear cratering shots in hard rock media on Pahute Mesa at the Nevada Test Site. The BUGGY event was a row-charge detonation employing five devices. The SCHOONER event of December 1968 was a larger example of nuclear cratering in hard rock and has provided an opportunity to study the distribution of radioactivity in nuclear crater ejecta where several factors varied significantly from the SEDAN detonation in Yucca Flat.

Few data are available on the distribution of radionuclides in nuclear crater ejecta. The distribution and mobility of radionuclides remaining in crater ejecta have considerable significance in any of the large scale engineering projects being considered by the Atomic Energy Commission. The feasibility of such projects may well hinge upon the postshot movement and environmental pathways of radionuclides in nuclear crater ejecta, both from airborne debris or as radionuclides transported from the nuclear crater site in water. We find that two ecological mechanisms are

important in determining the feasibility of nuclear excavation projects - the movement and cycling of stable elements of radionuclides produced in an excavation event, and the pathways of water in natural environments. A portion of the current research in the Bio-Medical Division, Lawrence Radiation Laboratory, is directed toward these topics.[6]

RESULTS AND DISCUSSION

Sedan Studies

During the few seconds that the mound of earth is being lifted by the force of the detonation, gaseous radioactivity permeates the mound or lofted overburden, and many radionuclides have already condensed on the inside of the mound before significant venting occurs. These are typically found on the surface of the throwout or bulk ejecta. The bulk ejecta is the earth material that moved essentially en masse from the uplifted mound onto the surrounding land surface. The initial distribution of radioactivity in nuclear crater ejecta therefore is at least partially dependent upon the physical and chemical behavior of the isotope species in the incandescent plasma during the process of crater formation.

Another class of material produced in nuclear cratering experiments has been called missile ejecta.[7] This type of ejecta is composed of particles which are placed on high trajectories above the crater and which fall through the vented cloud onto the bulk ejecta at later times, and at farther distances from the crater. Missile ejecta may be deposited with base surge materials and exhibits a continuum relationship with the close-in fallout.

The distribution of radionuclides in the ejecta of SEDAN crater has been discussed by Koranda et al.,[3] Koranda et al.,[4] and Koranda and Martin.[5] Their findings indicate that those refractory radionuclides which are prominent in nuclear crater ejecta, are deposited in the highest concentration on the surface of the bulk ejecta around the crater.

Tritium distribution, however, has been considerably modified by postshot environmental effects. Figure 1 shows the distribution of tritium and gross gamma radioactivity in the SEDAN crater lip at four stations in May 1966. Gamma radioactivity drops rapidly with depth and at the depth where tritium maxima occur, it is only slightly above the background for preshot earth materials at the SEDAN site. No early tritium concentrations in SEDAN ejecta were made, therefore it is not possible to compare these data with early measurements. Based on experience and data obtained from other cratering experiments, tritium concentrations in SEDAN ejecta were very likely high in surface strata, decreasing with depth until contact with the buried preshot soil materials was reached. During the period after the detonation, the effects of seasonal rainfall and soil water movements have completely modified the initial distribution.

The mean annual rainfall received at the U.S. Weather Bureau Station near SEDAN crater is 3.1 inches. The portion of the annual rainfall that is effective in modifying tritium distribution in SEDAN ejecta is received in the winter. Usually the winter rainfall does not penetrate below 24 inches in northern Yucca Flat, but in recently disturbed materials one might expect greater penetration. An unusually high winter rainfall in 1965-66 at the Nevada Test Site produced dilution of soil water tritium

concentrations at the 3 foot depth, as shown in Figure 2. In Figure 3, the distribution of rainfall for several years during the period of these measurements is shown.

Continuing measurements of tritium movement in sedan crater ejecta indicate that maximum tritium concentrations move in and out of the sampling zone (6-8 feet) accessible to us with hand tools. Data obtained from 3 stations on SEDAN crater lip are shown in Figures 4, 5, and 6. These data are expressed as disintegrations of tritium per gram of dry ejecta which eliminates the effect of variations in water content of the ejecta. The effects of a very large flux of winter rainfall received in January-February 1969 are evident in these data. Rainfall received in January 1969 immediately lowered concentrations in surface strata at the 1 foot depth, and by February dilution was evident in the deeper strata.

If the vertical distribution profile of tritium in the SEDAN ejecta is integrated and appropriate bulk density values are applied, the tritium data shown in Figures 4, 5, and 6 may be expressed in surface units of curies per square foot. Integrated surface tritium concentrations at 4 crater lip sites for a 3 year period are shown in Figure 7. The mean integrated surface concentration for the 4 crater lip sites in May 1966 was approximately 48 mCi/ft^2, and in August 1969, the mean concentration was approximately 21 mCi/ft^2. In the 3 year period, approximately 27 mCi/ft^2 were lost from the ejecta on SEDAN crater lip. This loss was mainly by evapotranspiration of soil water during the summer, but it is also apparent in the data shown in Figures 3, 4, and 5 that movement of soil water below the depth of sampling (8 feet) must occur. The heavy winter rainfall of 1969 caused considerable dilution in soil water tritium concentrations in the zone 1-6 feet and produced effects throughout the summer of 1969 as soil water was dissipated by evaporative and transpirational losses. Succulent plant cover in the form of dense growths of the summer annual, Salsola kali (Russian thistle), is present on SEDAN ejecta. Tissue-water concentrations in this plant species are essentially in equilibrium with the soil water tritium concentrations in the root zone.

It is apparent from these data that climatic, geologic, and biological parameters play an important role in the postshot distribution and movement of tritium in nuclear crater ejecta. The radionuclide present in SEDAN ejecta at this time in the highest concentration is tritium (greater than 20 mCi/ft^2).[6] Other radionuclides, even the more soluble ones such as Cs^{137}, which is not particularly prominent in nuclear crater ejecta, do not exhibit the degree of movement that tritium does in SEDAN ejecta. A very subtle level of Cs^{137} leaching[4] has been demonstrated in SEDAN ejecta, but most gamma-emitting radionuclides have remained in the surface strata of the ejecta where they were deposited.

Schooner Studies

In December 1968, the SCHOONER event produced a nuclear crater with an apparent average radius (R_a) of 129.9 meters and an apparent average depth (D_a) of 63.4 meters.[5] The SCHOONER crater and its ejecta field are shown in Figure 8 which is a low level aerial photograph. Fine ejecta and some large missiles were deposited beyond 3000 feet from ground zero (GZ). The main purpose of the SCHOONER experiment was to examine cratering phenomena in a hard rock medium at intermediate explosive yields.

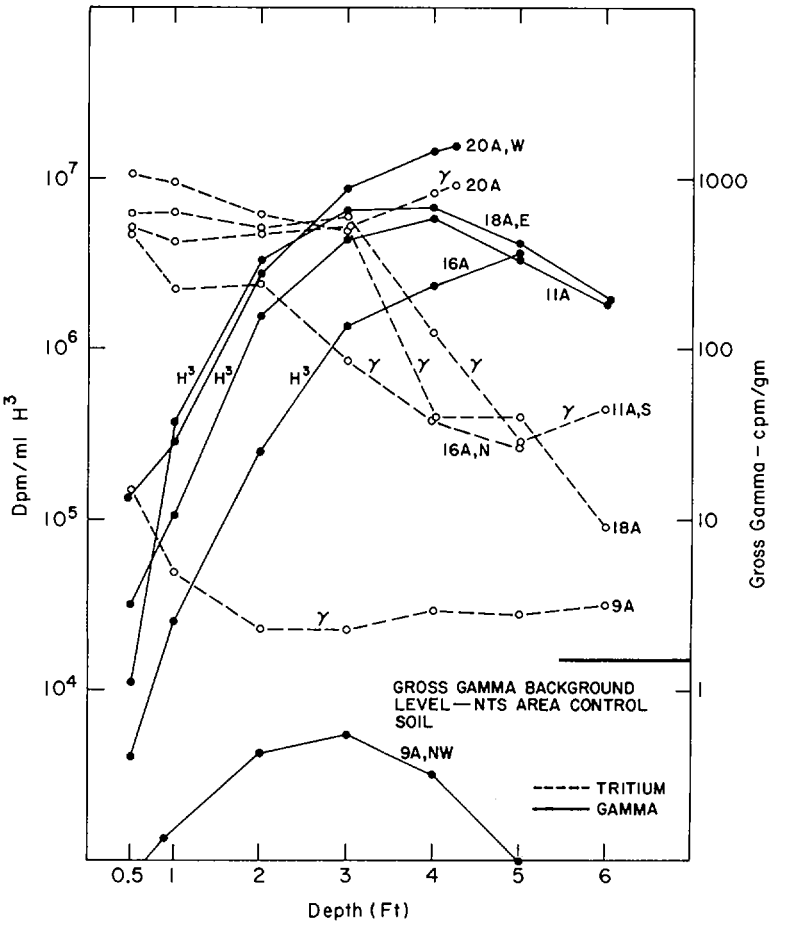

Figure 1

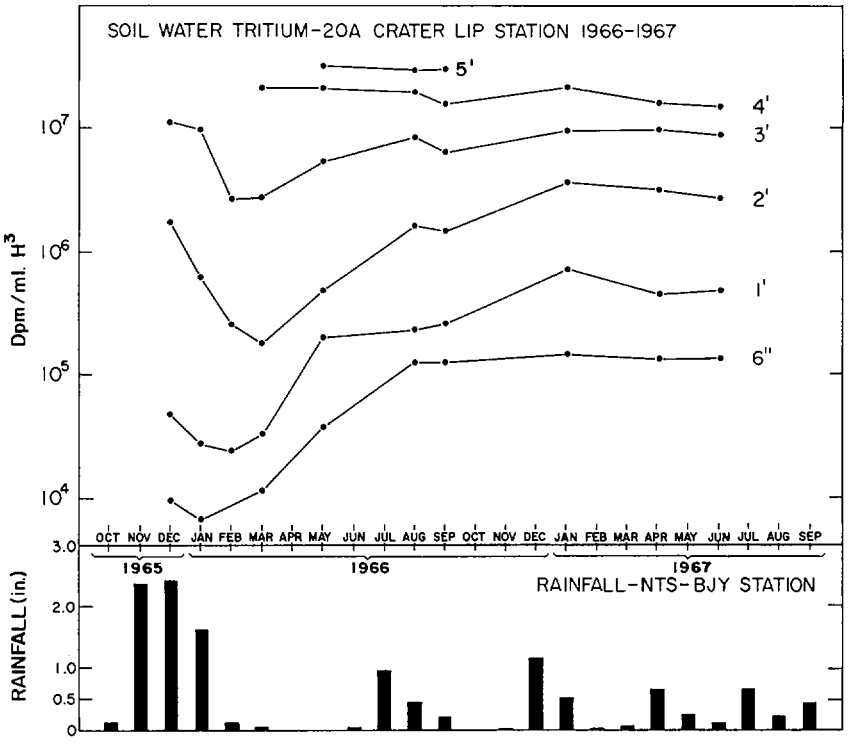

Figure 2

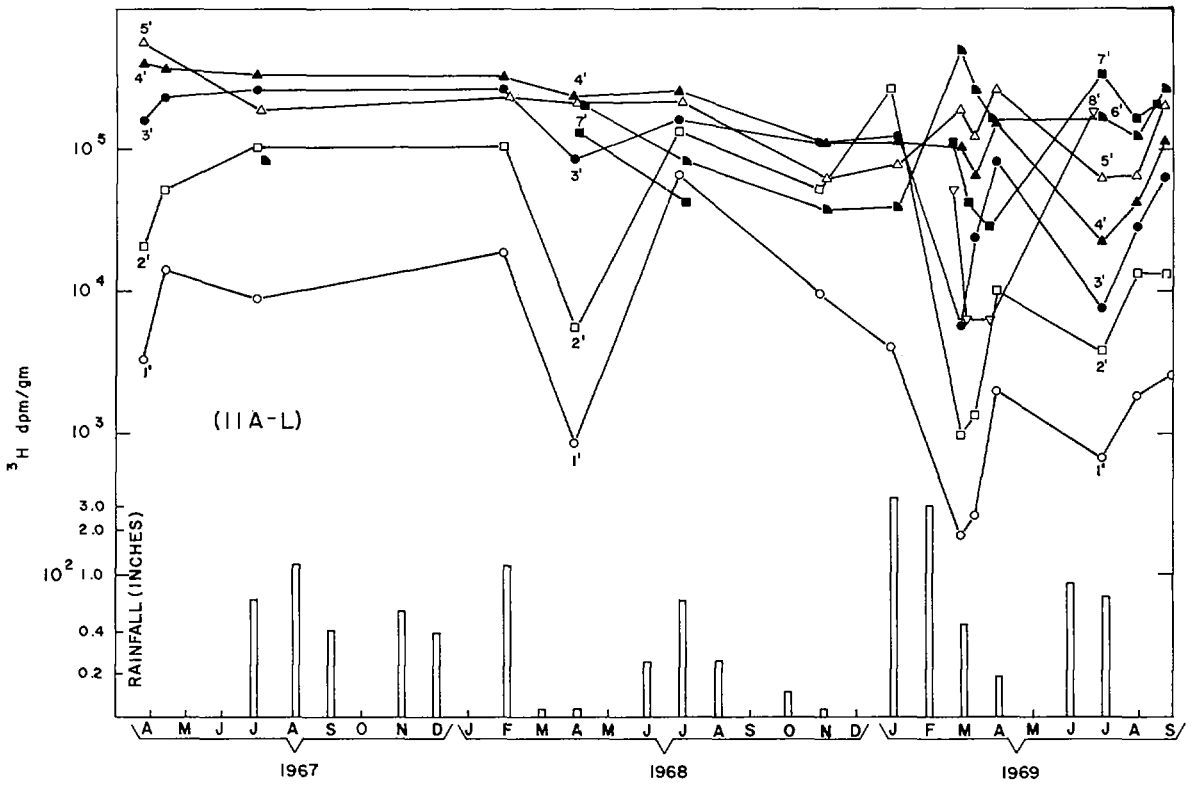

Figure 3

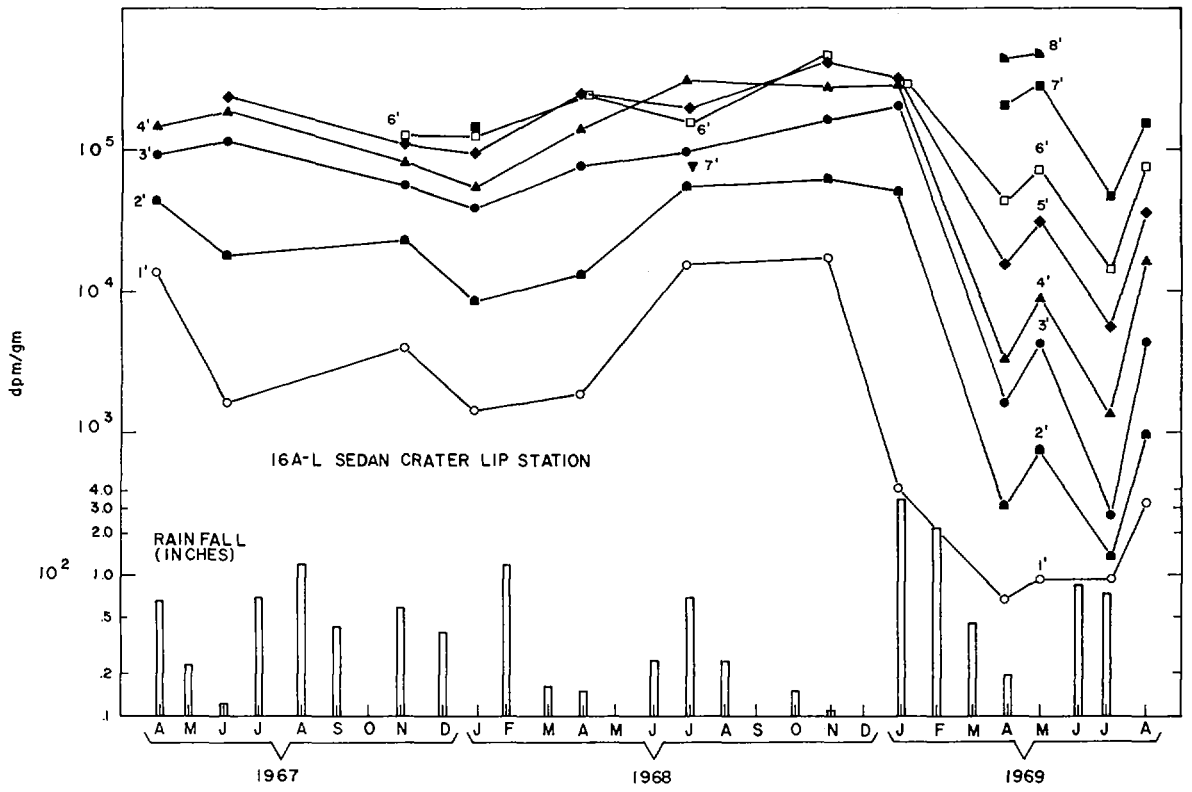

Figure 4

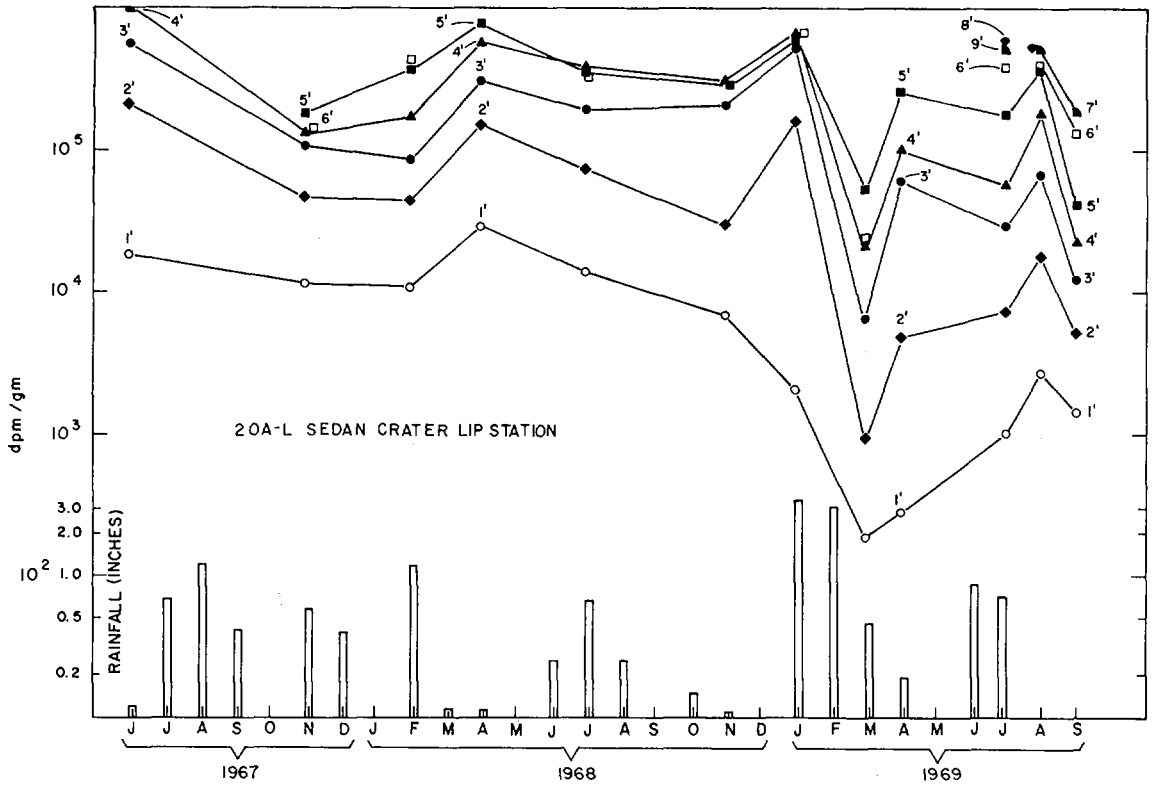

Figure 5

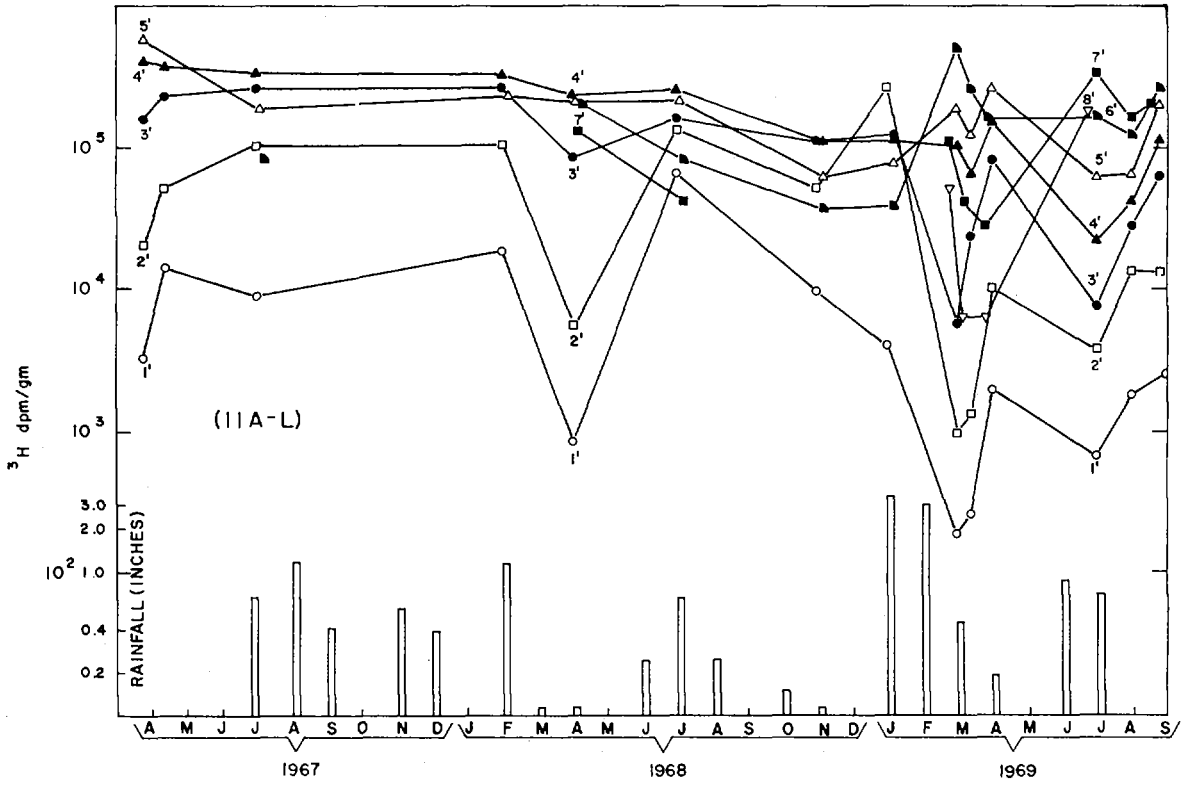

Figure 6

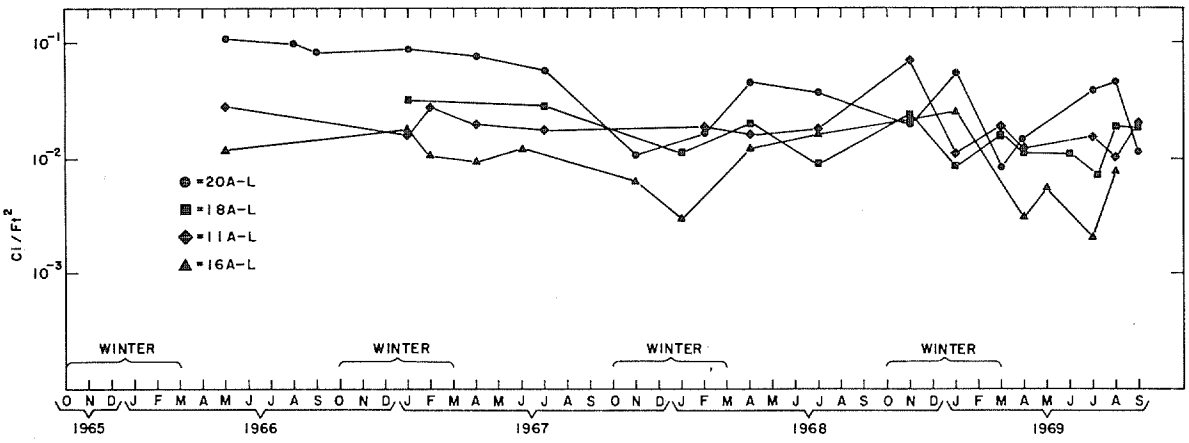

Figure 7

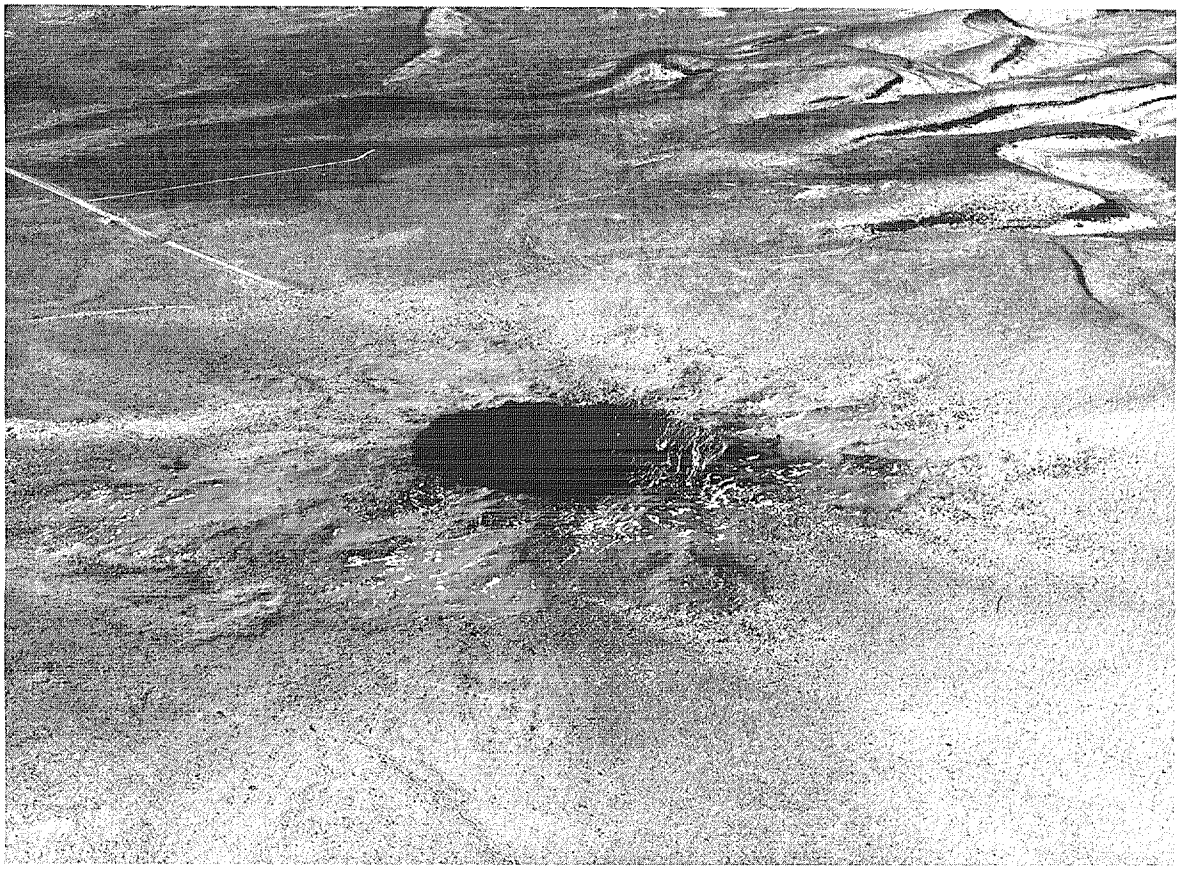

Figure 8

In January 1969, a series of ejecta samples were obtained at a distance of 3000 feet from GZ as sampling equipment was retrieved. An additional series of ejecta samples was obtained along a transect of the ejecta from the southeast edge of the throwout zone to approximately 800 feet from the crater lip. Concentrations of tritium and W^{181} in these samples have already been reported in preliminary report.[8]

In May and June 1969, it was possible to excavate a trench through the SCHOONER ejecta from 2000 feet from the crater to the crater lip on the southeast side of the crater. Figure 9 shows a phase of the excavation operation. Ejecta samples were collected from the wall of this trench at 1 foot depth intervals, and approximately every 50 feet along the trench. Surface ejecta and sub-ejecta samples at a depth of 1 foot were collected from 2500 feet from the crater to the edge of the throwout.

SCHOONER trench samples were processed in the manner described previously and tritium concentrations in the interstitial water, and gamma-emitting radionuclide concentrations per gram of dry ejecta were determined. A portion of the data obtained in the SCHOONER trench study will be presented here.

The concentrations of 6 radionuclides in vertical cross-sections of SCHOONER crater ejecta are shown in Figures 10 through 16. In the radionuclide profile of SCHOONER crater lip, shown in Figure 10, the distribution of radioactivity drops to a low concentration at a depth of 5-6 feet for all radionuclides. Concentrations at the maximum depth sampled (14 feet) are close to those found at the ejecta surface, while at 5-6 foot depth certain radionuclides were not detected. The deep region of radio-activity in the crater lip may be explained by the injection of radionuclides into the fractured, uplifted materials at the edge of the mound. This fractured, uplifted zone is later covered by bulk ejecta as the mound breaks up, and large masses of the mound at the contact of the uplifted zone may "hinge" and overturn onto the surface of the uplifted crater lip. High radioactivity is therefore found in the fractured, uplifted zone, and on the surface of the bulk ejecta. Certain radionuclides such as tritium and radioisotopes of tungsten permeate the mound and are found in relatively high concentrations throughout the bulk ejecta and the uplifted zone. Radionuclides that condense at high temperatures, and which begin to do so on the inside of the mound before it breaks up, are found mainly on the surface of the bulk ejecta, but also are apparently injected into the uplifted, fractured materials forming the crater lip.

If this is the mechanism that takes places radioactivity at depths of 14 feet in the crater lip, then at greater distances the increase in radioactivity in the deeper strata of the ejecta will not take place because the range of the injection phenomenon will not be very great. At 650-700 feet (Figures 12 and 13), only a small second peak of activity occurs. The stratum of lowered activity at 650-700 feet from the crater still occurs at a depth of 5 feet, however. There has not been enough rainfall to produce large scale leaching, especially of refractory radionuclides such as Nb^{95} and Y^{88}, and therefore these activity peaks are not zones of accumulation, but are depositional phenomena.

At 800 feet from the crater lip, the concentrations of five radio-nuclides decrease gradually with depth until the preshot soil surface is

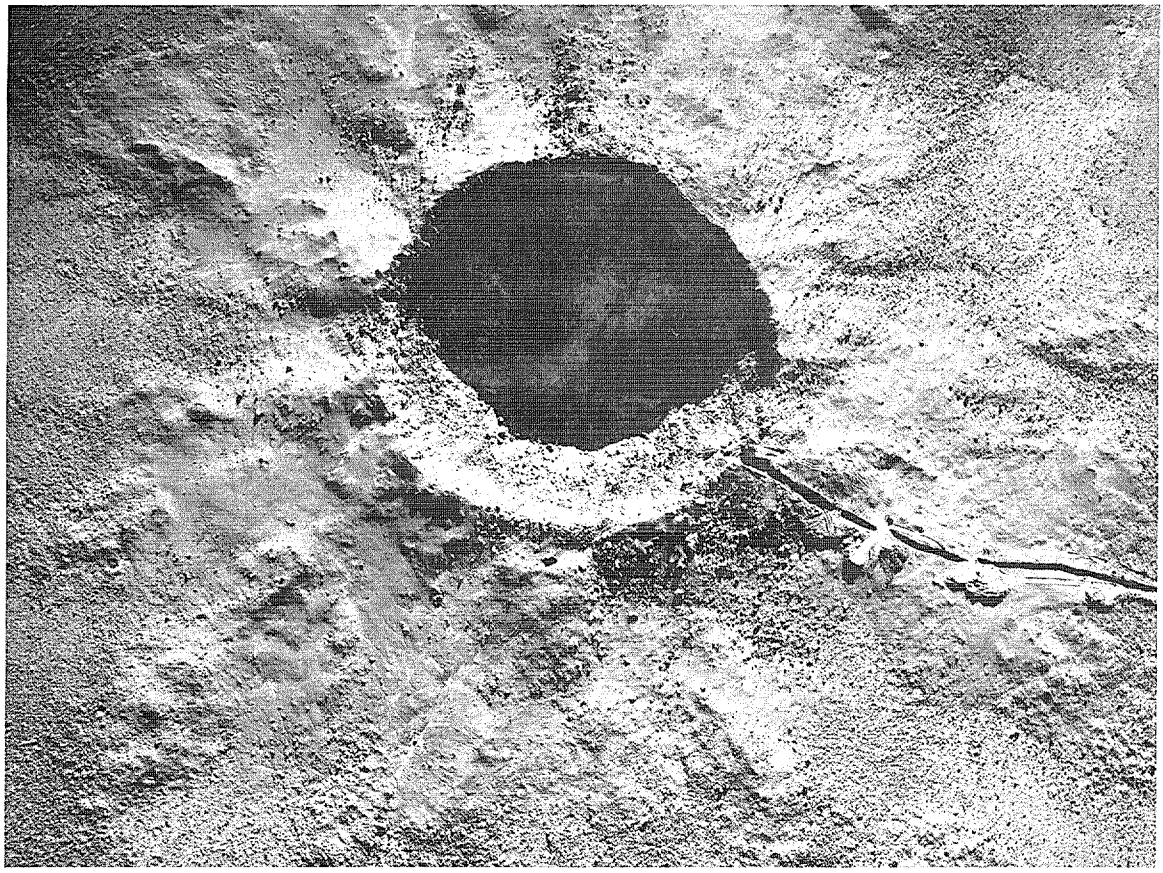

Figure 9

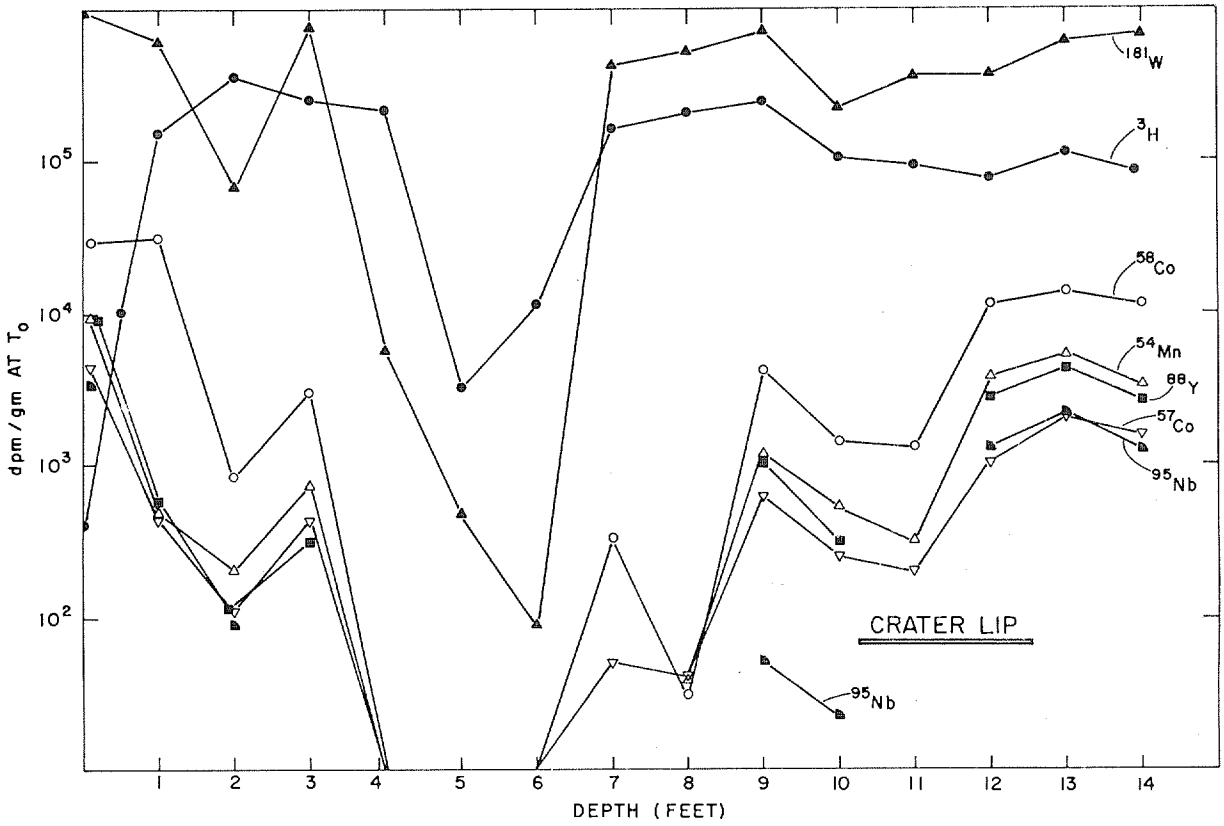

Figure 10

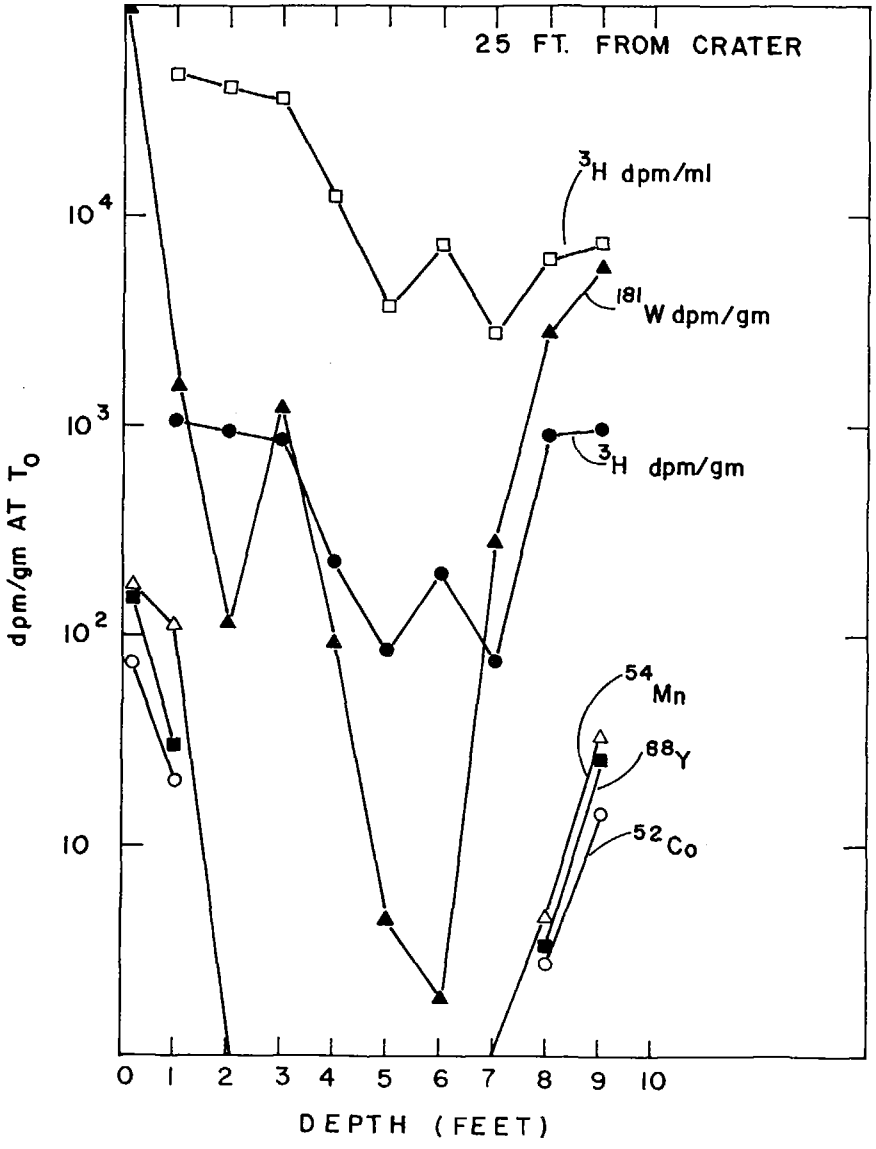

Figure 11

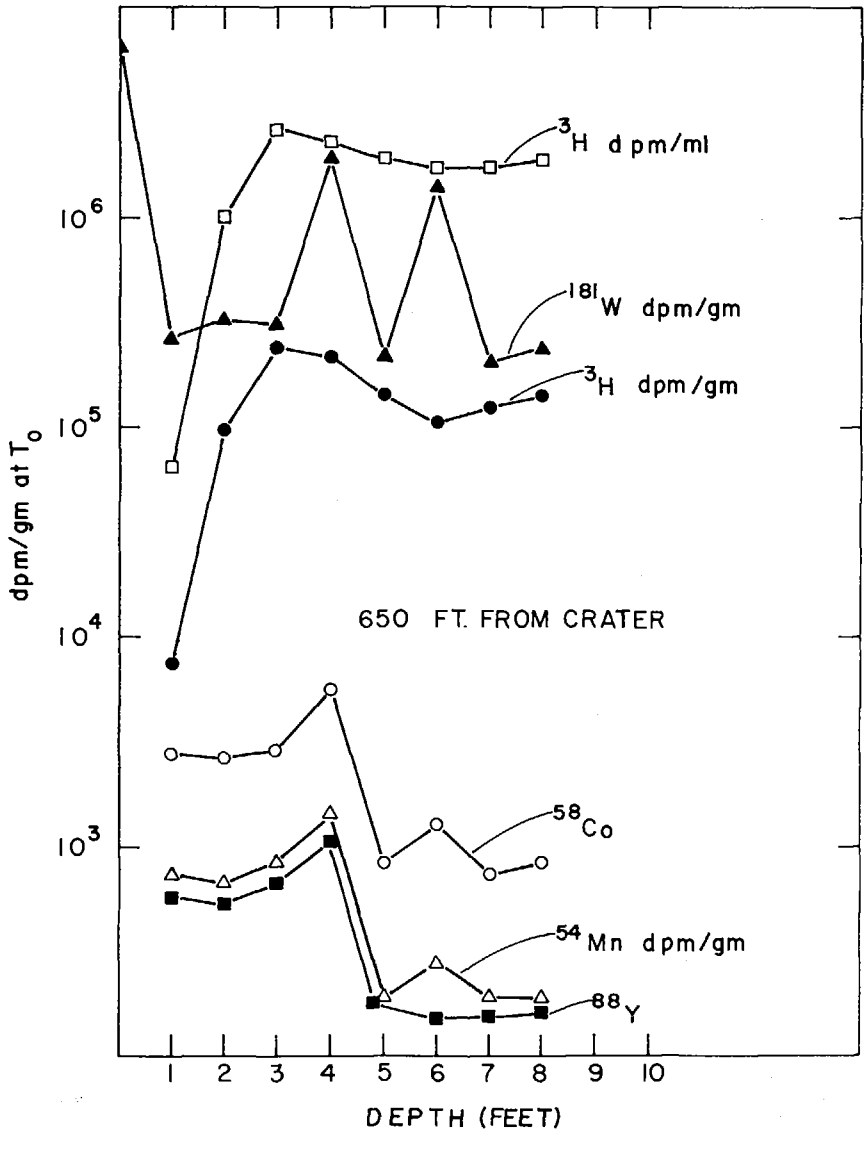

Figure 12

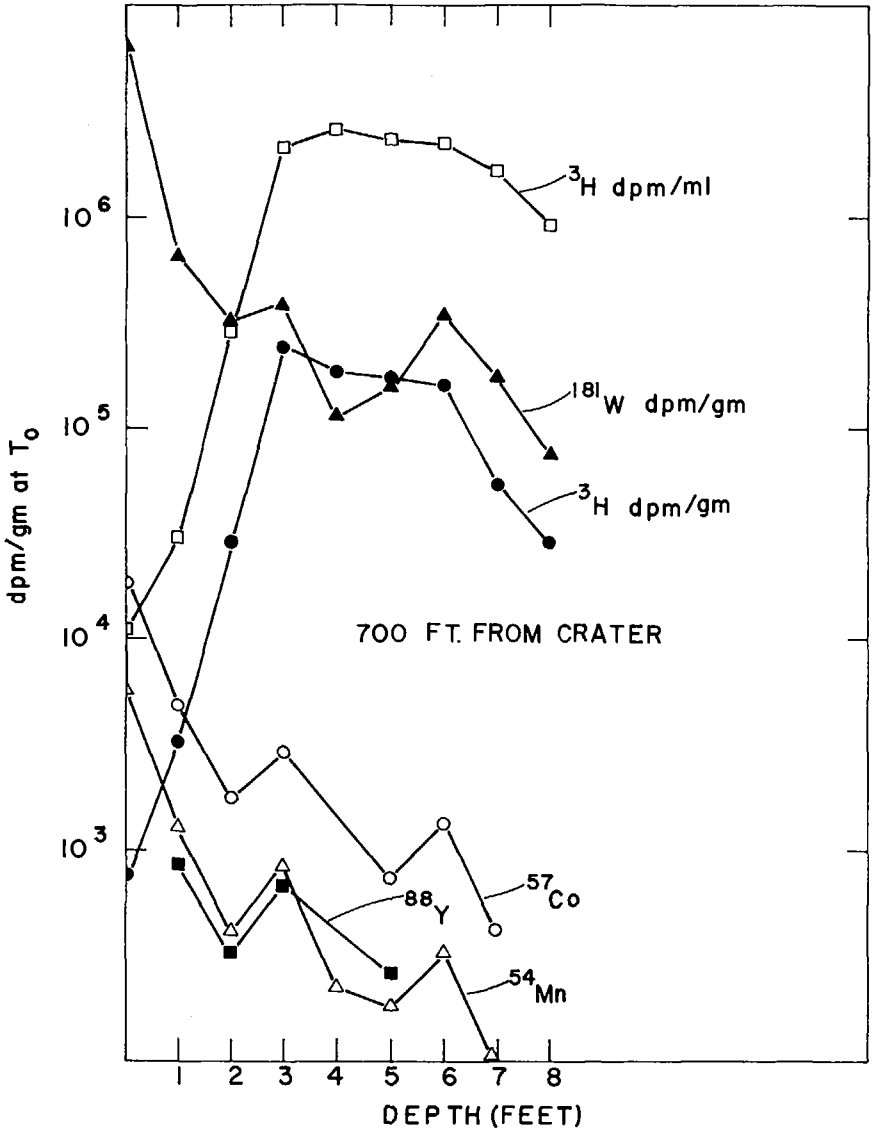

Figure 13

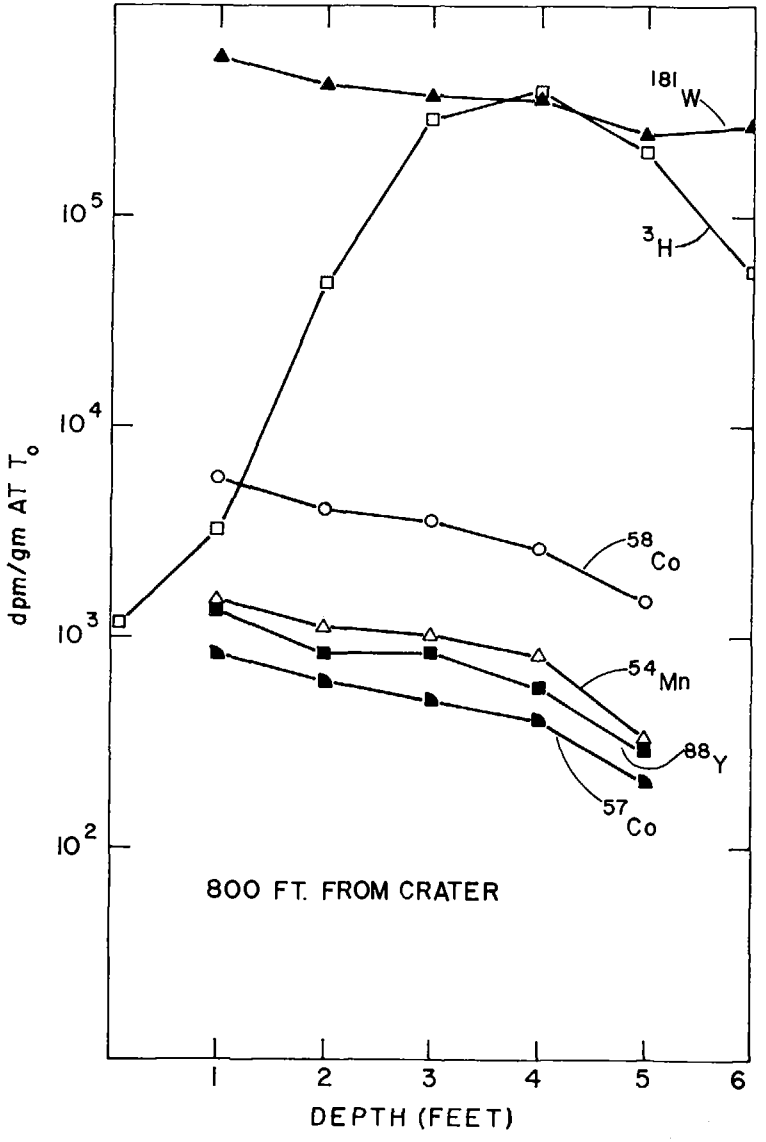

Figure 14

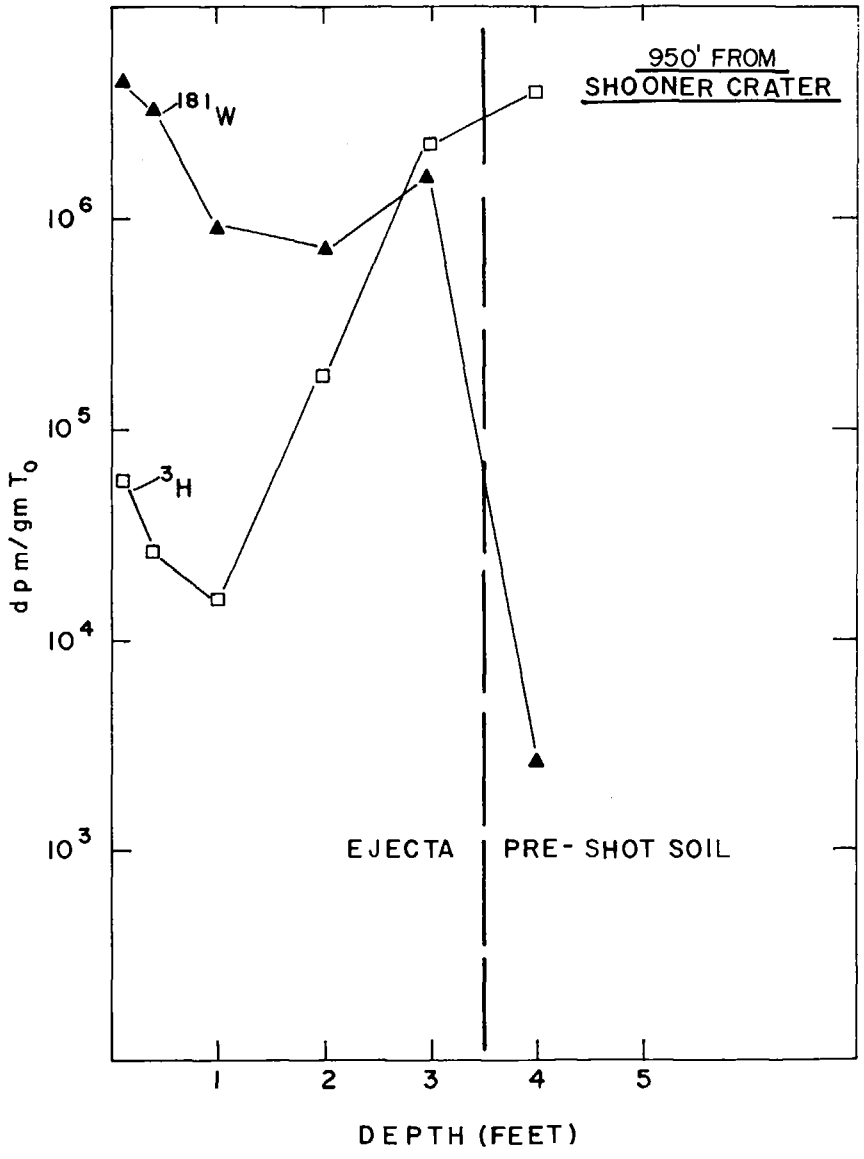

Figure 15

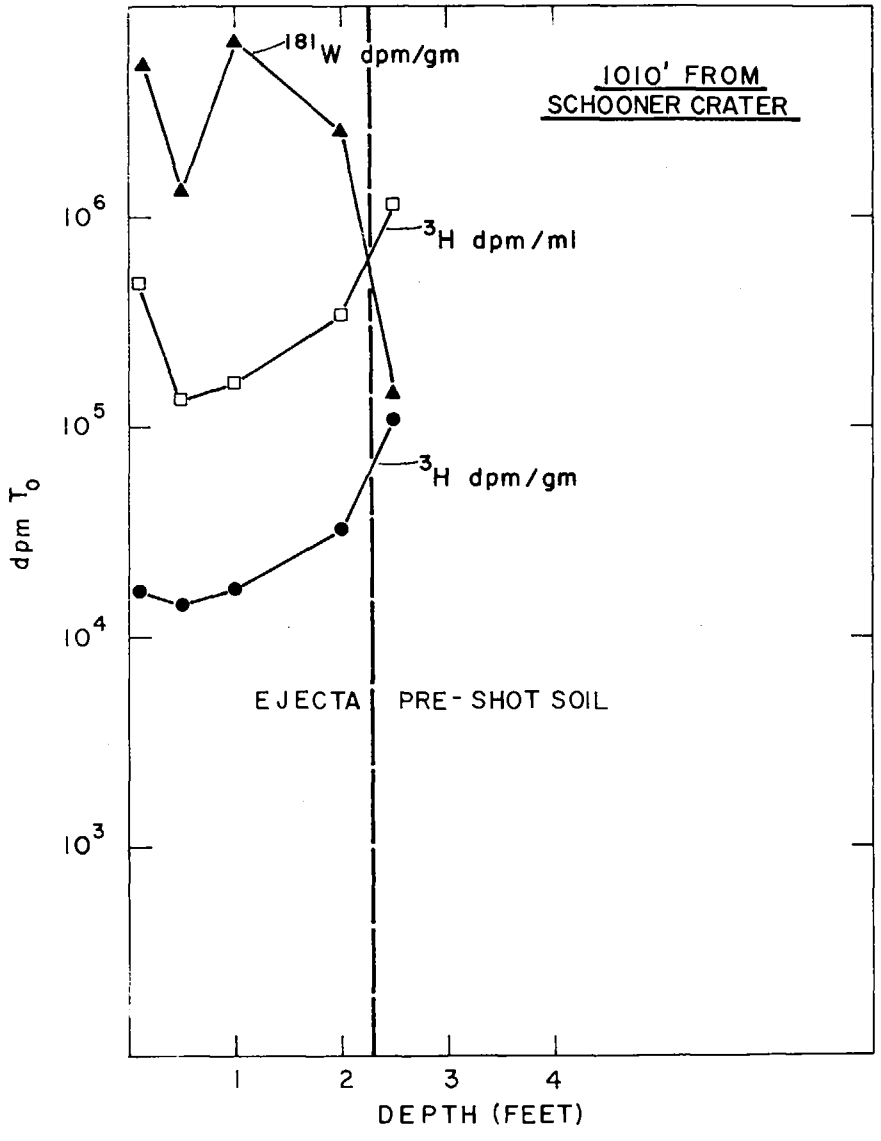

Figure 16

reached at 5 feet. Tritium distribution has been affected by winter and spring rainfall and the peak concentration is seen at 4 feet at the 800 foot station. Peak tritium concentrations are seen at 3 feet at 650 feet and 700 feet from the crater. The second tritium peak seen at depths of 9-14 feet in the crater lip profile is not believed to be caused by rainfall leaching and is a depositional feature.

At 950 feet from the crater, ejecta was approximately 38 inches deep. The distribution of W^{181} and H^3 at that site are shown in Figure 15. W^{181} activity drops rapidly when the parent material is reached whereas tritium activity reaches a maximum in the sub-ejecta preshot soil. This condition is repeated at 1010 feet from the crater, shown in Figure 16, where ejecta is approximately 28 inches deep, and maximum tritium activity in dpm/ml of soil water and dpm/gram of dry soil occur in the sub-ejecta soil.

The data obtained from the samples of ejecta taken from the zone of bulk ejecta transected by the SCHOONER trench indicate that radionuclide concentrations do not decrease continuously with depth, and that strata of high activity occur within the bulk ejecta. The excavation of CABRIOLET crater ejecta did not reveal a distribution of radioactivity as described here for the SCHOONER crater. The SCHOONER crater is the largest nuclear crater created in hard rock and it is possible that in higher yield detonations more uplift and fracture of the contiguous surface geology occurs, allowing radioactivity to be injected into this zone during or prior to venting. The complete analysis of SCHOONER trench data will reveal the extent of the deeper stratum of radioactivity and permit more conclusive statements concerning the distribution of radionuclides in SCHOONER ejecta.

From 1100 feet from the crater to the edge of visible ejecta, a thin covering of fine radioactive particles covers the preshot soil surface. This material is easily transported by the strong winds characteristic of the high desert climate, and at this time most of the ejecta deposited at 3000 feet from GZ has been moved by the wind. This area of shallow ejecta deposits was sampled in May and June 1969 when the trench was excavated. Data from 7 sampling sites in this area are shown in Table I. It is apparent that certain radionuclides have been leached from the surface layer of ejecta into the preshot soil profile. Tritium is the most mobile of the radionuclides in the ejecta and in most cases higher concentrations of tritium are found in the sub-ejecta preshot soil water. W^{181}, Co^{57}, and Mn^{54} also appear in the sub-ejecta soil, presumably having been leached by the same rainfall that translocated tritium from the ejecta into the preshot soil materials.

In January 1969, ejecta samples were obtained at a distance of 3000 feet from GZ as sampling equipment was retrieved. In Figure 17, data obtained at a site 3000 feet southeast of SCHOONER GZ during the first year postshot are shown. The sub-ejecta soil shows an accumulation of W^{181} where activity increased by approximately a factor of 4 during the 360 day period. Soil depths in this area are quite shallow and the parent material (bedrock) is usually encountered at depths less than 2 feet so that it will not be possible to follow the movement of W^{181} to any great depth in this soil system.

TABLE I

SPECIFIC ACTIVITY OF EJECTA COLLECTED AT THE EDGE OF SCHOONER CRATER EJECTA FIELD

	dpm/gram dry ejecta at T_0					
	H^3	Co^{57}	Mn^{54}	Nb^{95}	Y^{88}	W^{181}
1400 ft. surface	3.57×10^2	1.69×10^3	3.14×10^3	1.04×10^3	2.70×10^3	5.65×10^6
1400 ft, 1 foot	1.10×10^3	2.24	----*	----	----	1.16×10^4
1500 ft, surface	1.94×10^2	1.17×10^4	2.83×10^4	8.72×10^3	2.28×10^4	2.47×10^6
1500 ft, 1 foot	3.69×10^2	----	----	----	----	1.40×10^5
1600 ft, surface	1.39×10^3	2.95×10^3	5.73×10^3	2.63×10^3	4.82×10^3	1.10×10^7
1600 ft, 1 foot	3.65×10^1	----	----	----	----	1.92×10^4
2000 ft, surface	4.53×10^1	3.43×10^3	7.33×10^3	2.04×10^3	6.20×10^3	1.58×10^6
2000 ft, 1 foot	1.48×10^3	4.04	----	----	----	2.81×10^5
2100 ft, surface	1.64×10^2	1.40×10^3	2.53×10^3	9.26×10^2	2.08×10^3	1.20×10^7
2100 ft, .5 foot	51.9	----	----	----	----	1.01×10^4
2100 ft, 1 foot	79.8	----	----	----	----	1.49×10^4
2250 ft, surface	1.71×10^2	8.86×10^2	1.64×10^3	6.30×10^2	1.27×10^3	1.07×10^7
2250 ft, .5 foot	4.64×10^2	5.07	----	----	----	1.04×10^7
2250 ft, 1 foot	9.60×10^2	----	----	----	----	1.36×10^4
2350 ft, surface	2.50×10^2	1.24×10^3	2.21×10^3	9.70×10^2	1.65×10^3	1.31×10^7
2350 ft, .5 foot	3.17×10^2	16.3	31.0	----	----	4.57×10^4
2350 ft, 1 foot	7.80×10^2	----	----	----	----	7.36×10^5

*Not detected

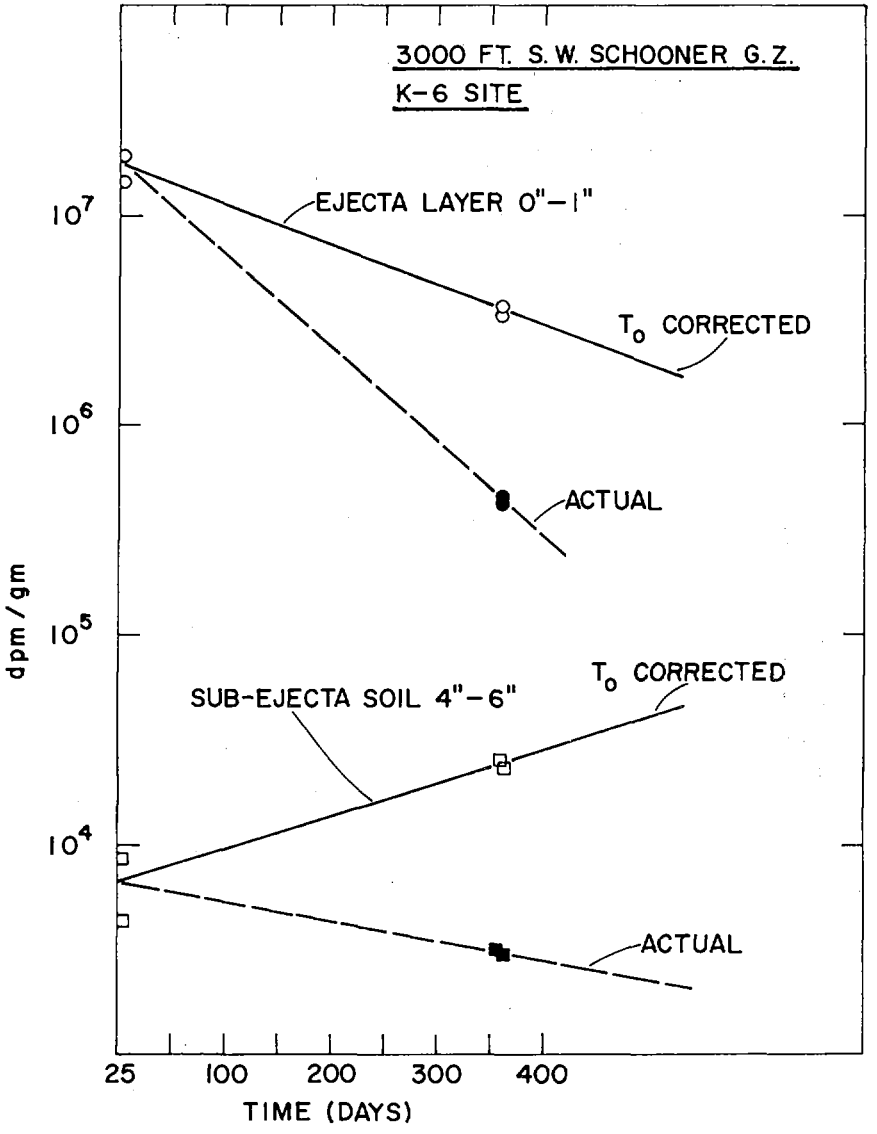
3000 FT. S.W. SCHOONER G.Z.
K-6 SITE
EJECTA LAYER 0"–1"
T_o CORRECTED
ACTUAL
SUB-EJECTA SOIL 4"–6"
T_o CORRECTED
ACTUAL
10^7
10^6
10^5
10^4
dpm / gm
25
100
200
300
400
TIME (DAYS)

Figure 17

The crater ejecta and close-in fallout represent a physical continuum of particles with a common source - the crater. The specific activity of ejecta from the surface of the crater lip, from the bulk ejecta area, from the base surge area, and from more distant fallout collection sites, is shown in Table II. Tritium concentrations decrease gradually with distance from the crater as the particles absorb more atmospheric water, and the tritium adsorbed on them becomes more diluted. Other radionuclides such as Co^{57}, may decrease slightly at 1-2 miles from GZ, but all radionuclides, except tritium, have essentially the same specific activity at 17 miles as they have at the crater lip. The specific activity of radionuclides in or on particles collected at 3000 feet, 4800 feet, 6000 feet, at 2 miles, and at 17 miles are shown in Tables III, IV, V, VI, VII, and VIII. These specific activity data when compared to those shown for bulk ejecta at the crater lip are seen to vary by less than a factor of 5 except for tritium. Tritium measurements on fallout particles made in the SCHOONER event could have been affected by losses before tray samplers were retrieved. Improved, self-closing trays will eliminate most of these losses in future experiments.

SUMMARY

Data obtained in long-term studies at SEDAN crater indicate that tritium is the most abundant radionuclide present in the ejecta at this time and that it exhibits complex movements which are correlated with seasonal soil water movement. Gamma radioactivity in SEDAN ejecta has not undergone any large translocations since shot-time.

The distribution of radionuclides in SCHOONER ejecta has been described in a series of cross-sections of the bulk ejecta of that crater. Two strata of high radioactivity were found in the crater lip, 1 at the surface and 1 at depths below 10 feet. Beyond 700 feet from the crater, radioactivity was found to decrease gradually with depth.

At the edge of the SCHOONER ejecta field, postshot movement of radionuclides was demonstrated by the presence of H^3 and W^{181}, and to a limited extent of Co^{57} and Mn^{54}, in the sub-ejecta preshot soil. The availability of these radionuclides in laboratory experiments with SCHOONER ejecta (Preliminary Report) corroborates the mobility of these isotope species.

The specific activity of radionuclides along the ejecta continuum namely, at the crater lip, in bulk ejecta, in the base surge area, and in fallout - has been compared. Except for some small variations along this particulate continuum, the specific activity of radionuclides on particles obtained at 17 miles, except for tritium, was very similar to that found on the crater lip.

TABLE II

SPECIFIC ACTIVITY OF RADIONUCLIDES

IN SURFACE EJECTA AND FALLOUT FROM SCHOONER

NUCLEAR CRATER

	Crater Lip	800 ft from Crater	4800 ft from GZ*	2 miles from GZ*	17 miles from GZ*
Co^{57}	4.31×10^3	2.30×10^3	6.59×10^3	7.33×10^2	4.13×10^3
Mn^{54}	9.62×10^3	6.20×10^3	1.09×10^3	6.50×10^3	8.33×10^3
Nb^{95}	3.37×10^3	2.10×10^3	5.38×10^3	3.53×10^3	3.51×10^3
Y^{88}	9.02×10^3	5.25×10^3	7.92×10^2	5.56×10^3	7.11×10^3
W^{181}	9.80×10^6	1.28×10^7	1.34×10^7	1.98×10^7	6.63×10^6
H^3	1.52×10^5	9.13×10^4	7.40×10^3	4.51×10^3	1.42×10^3

*Fallout tray samples.

TABLE III

SPECIFIC ACTIVITIES OF RADIONUCLIDES

IN FALLOUT PARTICLES COLLECTED IN 2 x 2 FOOT TRAYS

AT 3000 FEET FROM SCHOONER GZ

	SK-150A S-3 80° E.N.	SK-149C S-3 80° E.N.	SK-149B S-3 80° E.N.	SK-151A S-2A 30° E.N.	SK-152A S-2C 30° E.N.
	dpm/gram dry ejecta T_0				
Co^{57}	1.40×10^3	8.73×10^2	1.41×10^3	6.46×10^2	9.29×10^2
Ru^{103}	3.09×10^3	2.81×10^3	----	3.15×10^3	2.85×10^3
Mn^{54}	2.93×10^3	1.50×10^3	3.05×10^3	1.25×10^3	1.81×10^3
Nb^{95}	9.39×10^2	----	1.16×10^3	5.64×10^2	7.10×10^2
Co^{58}	9.13×10^3	5.10×10^3	9.15×10^3	3.82×10^3	5.78×10^3
Y^{88}	2.57×10^3	1.60×10^3	2.37×10^3	1.23×10^3	1.48×10^3
W^{181}	1.10×10^7	1.06×10^7	1.18×10^7	8.56×10^6	9.70×10^6
H^3	1.15×10^5	1.14×10^5	4.30×10^5	7.65×10^4	4.62×10^4
H^{3*}	1.22×10^6	8.15×10^5	1.46×10^6	4.04×10^5	2.52×10^5

*dpm per milliliter of adsorbed water extracted by vacuum distillation.

TABLE IV

SPECIFIC ACTIVITY OF RADIONUCLIDES

IN FALLOUT PARTICLES COLLECTED IN 2 × 2 FOOT TRAYS

AT 4800 FEET FROM SCHOONER GZ, 338° E. OF N.

	SK-146B	SK-146A	SK-148C	SK-147A	SK-145
	dpm/gram dry ejecta at T_0				
Co^{57}	7.01×10^2	6.33×10^2	6.16×10^2	6.56×10^2	5.92×10^2
Ru^{103}	2.87×10^3	2.49×10^3	2.09×10^3	2.35×10^3	2.65×10^3
Mn^{54}	1.29×10^3	1.23×10^3	9.87×10^2	9.77×10^2	9.84×10^2
Nb^{95}	6.26×10^2	4.86×10^2	----	5.01×10^2	5.39×10^2
Co^{58}	4.24×10^3	4.09×10^3	2.79×10^3	4.13×10^3	3.37×10^3
Y^{88}	9.60×10^2	8.53×10^2	4.54×10^2	8.85×10^2	8.08×10^2
W^{181}	1.27×10^7	1.74×10^7	1.27×10^7	1.27×10^7	1.16×10^7
H^3	7.34×10^3	3.34×10^3	7.87×10^3	6.80×10^3	6.68×10^3

TABLE V

SPECIFIC ACTIVITY OF RADIONUCLIDES IN FALLOUT

PARTICLES COLLECTED IN 2 × 2 FOOT TRAYS

AT 6000 FEET FROM SCHOONER GZ

	S-5-1 SK-144 32° E.N.	S-5-2 SK-142 32° E.N.	S-5-3 SK-143 32° E.N.
	dpm/gram dry weight at T_0		
Co^{57}	1.55×10^4	1.31×10^4	1.36×10^4
Ru^{103}	----	1.87×10^4	----
Mn^{54}	4.71×10^4	4.08×10^4	4.10×10^4
Nb^{95}	1.53×10^4	1.57×10^4	1.45×10^4
Co^{58}	1.27×10^5	9.94×10^4	1.08×10^5
Y^{88}	4.51×10^4	3.73×10^4	3.68×10^4
W^{181}	4.23×10^7	3.27×10^7	4.13×10^7
H^3	3.64×10^3	6.34×10^3	9.13×10^3

TABLE VI

SPECIFIC ACTIVITY OF RADIONUCLIDES IN FALLOUT

PARTICLES COLLECTED IN 2 × 2 FOOT TRAYS

AT 2 MILES FROM SCHOONER GZ

	S-12-1 SK-134 324° E.N.	S-12-2 SK-133 324° E.N.	S-13-1 SK-129 336° E.N.	S-13-2 SK-130 336° E.N.	S-16 SK-112A 53° E.N.
	dpm/gram dry weight at T_0				
Co^{57}	5.56×10^2	5.50×10^2	7.83×10^2	7.27×10^2	1.05×10^4
Ru^{103}	2.60×10^3	2.57×10^3	3.27×10^3	----	----
Mn^{54}	8.04×10^2	9.04×10^2	1.06×10^3	1.15×10^3	2.86×10^4
Nb^{95}	3.30×10^2	----	5.81×10^2	----	1.07×10^4
Co^{58}	3.09×10^3	3.31×10^3	4.10×10^3	3.64×10^3	8.15×10^4
Y^{88}	4.93×10^2	5.88×10^2	6.56×10^2	8.68×10^2	2.52×10^4
W^{181}	1.36×10^7	1.36×10^7	1.90×10^7	1.89×10^7	3.39×10^7
H^3	4.25×10^3	6.78×10^3	1.55×10^3	3.92×10^3	6.09×10^3

TABLE VII

SPECIFIC ACTIVITY OF RADIONUCLIDES IN FALLOUT

PARTICLES COLLECTED IN 2 × 2 FOOT TRAYS

AT 2 MILES FROM SCHOONER GZ

	S-14 SK-137 20° E.N.	S-14-1 SK-136 20° E.N.	S-14-2 SK-138 20° E.N.
	dpm/gram dry weight at T_0		
Co^{57}	6.05×10^3	7.92×10^3	8.17×10^3
Ru^{103}	----	----	----
Mn^{54}	1.64×10^4	2.24×10^4	2.29×10^4
Nb^{95}	5.58×10^3	7.70×10^3	7.25×10^3
Co^{58}	4.74×10^4	6.28×10^4	6.64×10^4
Ru^{106}	----	----	----
Y^{88}	1.29×10^4	2.18×10^4	1.97×10^4
W^{181}	2.73×10^7	3.26×10^7	3.49×10^7
H^3	7.18×10^3	7.39×10^3	4.40×10^3

TABLE VIII

SPECIFIC ACTIVITY OF RADIONUCLIDES IN FALLOUT

PARTICLES COLLECTED IN 2 × 2 FOOT TRAYS

AT 17 MILES FROM SCHOONER GZ

	S-43 SK-127 7° E.N.	S-44 SK-126 17° E.N.	S-45 SK-125 27° E.N.	S-46 SK-124 37° E.N.	S-47 SK-123 47° E.N.
	dpm/gram dry weight at T_0				
Co^{57}	1.27×10^3	8.59×10^2	1.17×10^4	2.44×10^3	4.48×10^3
Mn^{54}	1.87×10^3	1.57×10^3	2.30×10^4	5.57×10^3	9.76×10^3
Co^{58}	8.31×10^3	5.49×10^3	7.33×10^4	1.77×10^4	2.78×10^4
Y^{88}	1.82×10^3	1.26×10^3	1.91×10^4	4.69×10^3	8.69×10^3
W^{181}	3.73×10^6	6.19×10^5	6.66×10^6	1.36×10^6	2.08×10^7
H^3	1.63×10^4	3.63×10^3	1.58×10^4	4.23×10^3	3.14×10^4
Nb^{95}	----	8.56×10^2	7.76×10^3	1.97×10^3	4.47×10^3
Ru^{103}	----	----	----	2.88×10^3	----

REFERENCES

1. M. Nordyke and M.M. Williamson, "The Sedan Event," Lawrence Radiation Laboratory and U.S. Army Corps. of Engineers, Livermore, Rept. PNE-242F (1965).
2. J.J. Koranda, "Residual Tritium at Sedan Crater," 2nd Radioecology Symp., June, 1967, Ann Arbor, Mich. (1967).
3. J.J. Koranda, J.R. Martin, and R.W. Wikkerink, "Residual Tritium at Sedan Crater - Part II Soil and Ejecta Studies," Lawrence Radiation Laboratory, Livermore, Rept. UCRL-50360 (1967).
4. J.J. Koranda, J.R. Martin, and Robert W. Wikkerink, "Leaching of Radionuclides at Sedan Crater," 155th Natl. American Chemical Society Meeting, San Francisco, Calif., March 31-April 5, 1968.
5. J.J. Koranda and John R. Martin, "The Persistence of Radionuclides at Sites of Nuclear Detonations," Proc. Biomedical Symp., Biological Implications of the Nuclear Age, Lawrence Radiation Laboratory, Livermore, March 5-7, 1969.
6. B. Shore et al., "The Fate and Importance of Radionuclides in Plowshare Events," U.S. Public Health Service Symp., Las Vegas, Nevada, April 7-11, 1969.
7. R.H. Carlson and W.A. Roberts, "Project Sedan: Mass Distribution and Throwout Studies," The Boeing Company, Seattle, Wash., PNE-217F (1963).
8. L.R. Anspaugh et al., "Biomedical Division Preliminary Report for Project Schooner," Lawrence Radiation Laboratory, Livermore, Rept. UCRL-50718 (1969).