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RESULTS FROM SEDAN POSTSHOT DRILLING

Spent M. Hansen

December 1966

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Larry E. Williams
Authorizing Official

Date: 03/01/2007

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Scientific and Technical Information, National Bureau of Standards,
U. S. Department of Commerce, Springfield, Virginia 22151
Price: Printed Copy \$3.00; Microfiche \$0.65.

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CONTENTS

	Page
Abstract	1
Introduction	2
Purposes of Investigation	4
Summary of Work Performed	4
True Crater Surface	8
Characteristics of the Crater	10
Geophysical Logging Data and Evaluation	12
Laboratory Results	15
Summary and Conclusions	16
Appendix A Geophysical Drill Hole Log Data and Interpretation	17
Appendix B Procedure Used in Preparation of Ten Composite Samples from Drill Hole U64a	28
Appendix C Examination of Punch Core Samples from Drill Hole U64a	31
Appendix D Summary of Results of Radiochemical Analyses	36
Bibliography	37

RESULTS FROM SEDAN POSTSHOT DRILLING

ABSTRACT

Four holes were drilled near the bottom of the Sedan nuclear crater at the Nevada Test Site. Punch core samples were recovered periodically during the drilling. Density logs, caliper logs, radiation logs, and temperature logs were run in the holes.

The true crater surface was encountered at the depth of 822.4 ft below the preshot surface ground zero (192.4 ft below the point of detonation) in the hole nearest the crater center, and at shallower depths in the remaining three holes. The true crater surface is approximately hemispherical in shape.

Zones of increased density exist in the lower portion of the fallback and in adjacent regions outside the true crater surface. Maximum densities encountered are slightly greater than 2.2 g/cm^3 and represent an increase of approximately 20% above the preshot density.

The existence of open concentric fractures outside the true crater surface is supported by evidence from gamma radiation logs and air circulation loss. Radial fractures which transect the concentric fractures may also exist.

Elevated temperatures resulting from heat deposited by the nuclear explosion decrease laterally outward from the center of the crater. The region of highest temperature was encountered near the crater center at depths of 85 to 243 ft beneath the shot point. The maximum temperature recorded was 169.8°F .

Radiation logs show the occurrence of local zones of high and low radioactivity in each of the drill holes. The general trend is for gamma radioactivity to increase with depth to a maximum about midway between the shot point and the true crater surface.

Tritium analyses were made of punch core samples from the hole nearest the crater center. The results indicate that the bulk of the tritium remaining within the fallback lies above the shot point with the relative concentration decreasing rapidly and regularly with greater depth.

Punch core samples are not sufficiently distinctive to characterize the part of the crater from which they were taken. A greater amount of disaggregation of cemented alluvium, however, was noted inside the true crater surface.

INTRODUCTION

Sedan is the name of a nuclear cratering experiment conducted near the north end of Yucca Flat, Nevada Test Site during 1962 (see Fig. 1).^{*} The purpose of the experiment was to investigate the phenomena associated with the formation of a nuclear explosion crater in alluvium.

Fig. 1. Sedan crater looking northerly. Note layered character of undisturbed alluvium near crater lip. Fine-grained talus slopes below cemented alluvium outcrops consist of fallback.

The medium within which the Sedan Experiment was conducted is alluvial valley fill consisting of fragments of Tertiary volcanic rocks, limestone, quartzite, and shale. The alluvium shows local variation, both laterally and with depth. The gross characteristics, however, do not vary significantly, except for a depth dependent gradual increase of density.

Definite horizontal layering is present in the alluvium, although the individual layers are usually poorly defined and only local in continuity (see Figs. 2, 3). This layering is primarily the result of variation in size of the contained lithic fragments and in degree of caliche cementation. The thickness of

the alluvium at the Sedan site is 1410 feet. The underlying rock is a weakly cemented volcanic tuff.^{**}

^{*}Sedan Nuclear Crater Experiment:

Depth of burst	635 ft
Medium	Desert Alluvium
Date	July 6, 1962
Yield	100 ± 15 kt
Apparent-crater depth	323 ft
Apparent-crater radius	610 ft

Coordinates:

North	884000.00
East	681000.00
Ground zero elevation,	3686.9 ft (above sea level)
Surface ground zero elevation,	4316.9 ft

^{**}See Richards, William D.

Fig. 2. Consolidated alluvium exposed near Sedan crater lip. Note contained, poorly sorted lithic fragments.

Fig. 3. Exposed bank of consolidated alluvium at west edge of Sedan crater. Note vertical gradation in size distribution of fragments and well-developed layering.

PURPOSES OF INVESTIGATION

The major objective of the postshot field exploration program was to obtain information on the quantity and distribution of radioisotopes left behind in the fallback, principally tritium. Secondary objectives included the following:

1. The location of the buried true crater surface with a greater degree of confidence than previously
2. The determination of physical properties of the fallback material above the true crater surface
3. The determination of physical properties of alluvium below the true crater surface
4. The determination of heat distribution, radioactivity distribution, and density change within and surrounding the crater
5. The development of a model of the Sedan crater and its environs

SUMMARY OF WORK PERFORMED

Drilling

Work within the Sedan crater commenced on April 30, 1964 and was completed on June 30, 1964 (see Fig. 4). At the locations shown in Fig. 5 four holes were drilled from sites within the bottom portion of the apparent crater. The following geophysical logs were run: temperature, gamma ray, density, and caliper. Samples from each of the drill holes were recovered and preserved for laboratory radiochemical analyses.

Drill Hole Data

U64a

Coordinates:	
North	883982.41
East	681026.13
Bearing from zero point	S 56° 04' E
Horizontal distance from zero point	31.50 ft
Ground elevation	3997.2
Collar elevation	3998.48
Hole depth	692-1/2 ft
Hole orientation	Vertical

Fig. 4. Aerial view of Sedan crater looking northerly. Drill rigs were positioned in flat area at crater bottom. The encircling bulldozed ring surrounding crater bottom flat was constructed as barrier for downward rolling rocks. Steel matting strip which served as roadway to crater bottom appears on west side of crater.

U64c

Coordinates:	
North	884048.12
East	681135.66
Bearing from zero point	N 70° 28' E
Horizontal distance from zero point	143.98 ft
Ground elevation	4016.44
Hole depth	489 ft
Hole orientation	Vertical

U64e

Coordinates:	
North	884001.87
East	680938.55
Bearing from zero point	N 88° 15' W
Horizontal distance from zero point	61.5 ft
Ground elevation	4000.3
Collar elevation	400.97

Fig. 5. Topographic map of Sedan crater showing location of U64 series of drill holes.

Hole depth	350 ft
Hole orientation:	
Inclination	45°
Direction	North

U64f

Coordinates:	
North	884052.67
East	681139.79
Bearing from zero point	N 69° 28' E
Horizontal distance from zero point	149.54

Ground elevation	4016.71
Collar elevation	4019.59
Hole Depth	250 ft
Hole orientation:	
Inclination	41° 26' from horizontal
Direction	N 70° 34' E

Sample Recovery and Preservation Techniques

The drilling in all four completed drill holes (described above) was carried out using rotary drilling techniques. Davis Mix (a mixture of detergent suds and water) was used as the drilling fluid whenever possible; but in some instances, because of poor consolidation in the alluvium surrounding the drill holes, drilling mud was used. Punch core samples were recovered from all of the drill holes although the interval varied from hole to hole and from portion of hole to portion of hole. The usual interval between samples was approximately 10 ft (see Appendix C).

Samples were recovered with a 2-ft-long punch core. Immediately before the taking of a sample, dry air was circulated throughout the bottom of the hole leaving the lower portion of the hole as free from drilling fluid as possible. The string of tools was then removed from the hole, the punch core barrel was attached to the end of the tool string, and the tools were replaced in the hole.

The punch core was then forced, by means of pressure exerted on the drill string and some rotary motion, into the undisturbed alluvium at the bottom of the drill hole. After the punch core had been forced approximately 2 ft into the undisturbed material, it was removed from the drill hole. The sample was then recovered from the core barrel, and the driest portion, usually only 6 or 8 in. from the central 2 ft of punch core sample, was placed in a wide-mouth mason glass jar. The mason jar was quickly sealed and marked. The exposure of the sample to the atmosphere was thus held to a minimum. Samples were then boxed and shipped to the Lawrence Radiation Laboratory, Livermore for examination and subsequent resampling for analyses (see Appendices B and C).

Geophysical Logs

Geophysical logging was done by the Birdwell Division of The Seismograph Service Corporation of Tulsa, Oklahoma. Mr. Don Dillard, Chief of Birdwell operations at Nevada Test Site, supervised the logging operations.

The Birdwell logging truck was parked on the west edge of the crater lip on the north side of the access pad, and the logging line was hand-carried to the bottom of the crater. The appropriate logging tools were attached for lowering into the respective

drill holes. The weight of the logging tool was sufficient to maintain the logging line as an arc from the spool on the logging truck directly to the drill hole and to keep the line from lying on the crater side. Usually about 450 ft of line was unreeled before the logging tool could begin its descent into the hole. The correction for line out was made by Birdwell, and hole depths were adjusted accordingly.

The following is a list of the logs run in the various holes:

Hole U64a

Density log (June 24)
Caliper log (June 24)
Gamma ray log (June 25)
Temperature log (June 25)

Hole U64c

Density log (June 13)
Gamma ray log (June 21)
Temperature log (June 21)

Hole U64e

Density log (June 6)
Caliper log (June 19)
Gamma ray log (June 19)
Temperature log (June 19)

Hole U64f

Density log (June 27)
Gamma ray log (June 30)
Temperature log (June 28)

A tabulated summary of the results from the above logging is included as Appendix A.

TRUE CRATER SURFACE

An interpretation of the position and configuration of the true crater surface is suggested within the limitations of the data available. A generalized east-west cross section through the Sedan crater showing the proposed location of the true crater surface and other pertinent features is included as Fig. 6. Unfortunately, the data obtained are not adequate to permit a positive determination of location and configuration of the true crater surface in the region where it is buried by fallback. The reasons for this are: (1) the gross characteristics of the shocked alluvium outside the true crater surface are nearly identical to those of the fallback material on the inside of the surface, and (2) the nature of the true crater surface at the bottom of nuclear craters has not been established to be a sharp contact and may be gradational.

Hole U64a

In hole U64a, near the center of the crater, the true crater surface is suggested at 504 ft below the drill collar elevation. This represents a total depth of 822.4 ft below

Fig. 6. Cross section of Sedan crater.

the preshot surface ground zero and 192.4 ft below the point of detonation.* The density log shows a general increase up to about 500 ft with increasing depth and thereafter a general decrease to the bottom of the hole. The maximum bulk density in the vicinity of about 500 ft as shown by the density log is approximately 2.2 g/cm^3 , or an increase of slightly more than 20% over average preshot density. The caliper log shows a definite smoothing out of the walls of the hole below about 490 ft and with much greater hole regularity and fewer washouts below this point than are characteristic of the upper portion of the hole.

The 504-ft depth of the true crater surface is selected principally on the basis of the temperature log. Caliper and density logs support this conclusion since they both place the true crater surface in the vicinity of 500 ft. Even without temperature log data, and based on data from the caliper and density logs alone, the lower true crater surface could be bracketed between about 490 and 510 ft. Examination of punch core samples from U64a also tends to confirm an approximate 500-ft depth.

*The elevation of the true crater surface at the lower surface of the true crater below hole U64a is 3494.5 ft (above sea level).

Hole U64e

The true crater surface was encountered at a depth of 238 ft below the drill collar in this hole. This interpretation is based principally on data from caliper and density logs. The caliper log shows a marked change from badly caved and washed out above 238 ft to rather constant hole size with few washouts below 238 ft. The density log indicates a fallback density maximum at about 232 ft of slightly greater than 2.2 g/cm^3 with a fairly regular decrease both up and down the hole.

Hole U64f

The density log of hole U64f does not permit a determination of true crater surface with confidence. However, a general increase in density near 173 ft suggests that the true crater surface may be located in this vicinity. Since a caliper log was not run in this hole and other logging data are inconclusive, the depth of 173 ft is tentatively suggested as the depth of the true crater surface. The maximum indicated bulk density in the vicinity of 173 ft is about 2.1 g/cm^3 .

CHARACTERISTICS OF THE CRATER

The lower portion of the true crater surface is considered to be approximately hemispherical in shape as represented on the cross section in Fig. 6. Zones of increased density occur both inside and outside the true crater surface. Concentric rebound fractures parallel to the lower portion of the true crater surface and radial fractures occur within the compacted zone.

Compacted Zones

A zone of compaction in the fallback begins about 50 ft below the zero point and increases downward with a maximum density of about 2.2 g/cm^3 at the true crater surface, near the crater center. This represents an increase of about 20% over the preshot density at these depths which was approximately 1.8 g/cm^3 .

The increase in density of the fallback material probably represents compaction caused by its downward fall after the collapse of the explosion gas bubble. This density increase indicates that the alluvium particles are packed together more tightly postshot

than in their undisturbed state and that intergranular pore space (porosity) has been reduced. Permeability may also have been reduced although no permeability measurements were made. This region of compacted fallback and decreased porosity may tend to trap tritium and other radionuclides more effectively than preshot permeability measurements may suggest. The existence of a zone of compacted fallback near the bottom of the true crater may decrease potential water loss downward by seepage.

Density logs from U64a indicate a gradual decline in density outside the true crater from approximately 2.25 g/cm^3 maximum to about 1.85 g/cm^3 at the bottom of the hole (181 ft below the true crater surface). Data on the preshot density at this depth are not available for comparison. Density logs of hole U64a indicate the presence of the compacted zone in that portion of the true crater at an elevation higher than the shot point. This increase of density outside the true crater surface is probably the result of compaction caused by shock and cavity gas pressure from the explosion.

Concentric Fractures

The existence of concentric fractures is supported by evidence from gamma ray radiation logs and from drilling air circulation losses. Drill hole U64a shows a single high-intensity gamma radiation peak centered at 595 ft and surrounded by radiation levels near background. Drill hole U64e shows a single peak at 330 ft. The existence and intensity of these narrow zones of higher radioactivity were carefully substantiated by relogging the holes in these regions using different instrument intensity settings. The peaks are considered to result from fractures containing radionuclides that intersect the drill holes.

Open fissures were encountered below the true crater surface in hole U64a at depths of 521 and 533 ft. At 521 ft, drilling air return circulation was lost in hole U64a while drilling through a 4-ft open fissure. Air was subsequently observed blowing out of hole U64e around the tools. At the time, U64c was at a depth of 485 ft with the drilling rig temporarily closed down. Field tests for radionuclides and for CO_2 and CO were conducted by the REECO radsafe representative on the air coming from U64c with significant amounts not detected. If the open fissure providing connection between U64a and U64c intersected the holes at 521 and 485 ft respectively, it would approximately parallel the true crater surface in that region and be concentric. Hole U64a penetrated a 1-ft open steam-filled fissure between 533 and 534 ft. Steam rushed out of the hole around the tools for about 20 min during which time radioactivity levels were measured and field CO_2 and CO tests were run. Field results indicated a high CO_2 content. No reliable numerical values of $\text{CO}_2\%$ content were obtained. The two open fissures were probably not connected.

Radial Fractures

Radial fractures may be present. Since the orientation of such fractures would place them approximately parallel to the drill holes, intersection with radial fractures would be unlikely. Radial fractures, however, would be expected to transect the concentric rebound fractures and may have provided access channels for radioactive materials and steam from the cavity to the concentric fractures during the time of cavity growth.

GEOPHYSICAL LOGGING DATA AND EVALUATION

Temperature Logs^{*}

Hole U64a

The maximum temperature encountered was 169.8°F at a depth of 504 ft in hole U64a. Temperatures in the other four drill holes show a substantially lower maximum than those encountered in this hole. The point of maximum temperature was surrounded by a broad region (between 394 and 548 ft) of high temperatures which was in turn surrounded on both top and bottom by regions of relatively sharp temperature decline.

The temperature distribution in this hole indicates a depth for the true crater surface below the preshot ground surface (D_t) of 504 ft.^{**} The sharp break in the temperature curve and rapid decrease in temperature which occurs at 548 ft suggests a possible alternate interpretation for the position of the true crater surface.

Hole U64c

This hole shows a maximum temperature of 135.5°F at the hole bottom. The temperature was still increasing as the bottom of the hole was reached. This suggests that maximum temperatures in the central portion of the crater may be beneath the true crater surface, since the bottom of the hole is 50 to 75 ft below the presumed location of the true crater surface. However, the temperature profile in this portion of the crater may be anomalous. No explanation for this high temperature region is offered, but the

* Numerical data from temperature logs are included in Appendix A.

** This conclusion is based on the assumption that the true crater surface coincides with the location of maximum temperature in the central portion of the crater.

maximum temperatures encountered are substantially lower than the maxima recorded at the true crater surface in hole U64a only 128 ft away.

Hole U64e

The maximum temperature of 84.5°F was encountered at hole bottom. This is within 10 to 15°F of the ambient ground temperature. The log at this point does not show a trend for either increase or decrease. Whether or not higher temperatures would be encountered in this part of the crater environment at greater depths is not known.

Hole U64f

The maximum temperature of 76°F was encountered within the top 9 ft and probably results from surface effects. The temperature decreased generally with increased hole depth. Near the hole bottom the temperature recorded was 68°F, which is about ambient ground temperature.

Conclusion

The conclusion is drawn that elevated temperatures resulting from heat deposited in the shot environment by the nuclear explosion decrease laterally outward from the center of the crater. The maximum temperature range was beneath the shot point at depths of 85 to 243 ft. The true crater surface is suggested at the maximum temperature encountered in hole U64a. This temperature of 169.8 was encountered at 192.5 ft below the shot point and 504 ft below the apparent crater bottom.

Density and Caliper Logs

Preshot density of the alluvium within which the Sedan experiment was conducted has a range of approximately 1.6 to 1.80 g/cm³. * Standard gamma-gamma density logs indicate a zone of higher density within the lower portion of the fallback material. An increase in density of the fallback begins about 50 ft beneath the zero point and shows a regular, gradual increase to a density value 2.2 g/cm³, or about 20% greater than preshot in the vicinity of the lower cavity boundary near the center of the crater. Beneath the true crater surface, density values show a regular, gradual decline. At the bottom of hole U64a, 188.5 ft beneath the true crater surface, the alluvium has a density of 1.85. This slightly higher density at the bottom of this hole may represent increase resulting

* See Richards, p. 19. The figure of 1.8 g/cc was given as an average between surface ground zero and the zero point (location of the nuclear explosive).

from the depth of burial and be independent of the nuclear explosion. The density logs from holes U64e and U64f also show a maximum increase in density in the vicinity of the true crater surface. This increase totals 15 to 20%. The use of Davis Mix in drilling the holes may have increased the alluvium density at the hole margin. This density would then have been recorded on the logs. This possibility was not evaluated.

Radiation Logs

The gamma ray radiation logs show the occurrence of local zones of high and low radioactivity in each of the four drill holes. The spacing of the holes was too great and the radiation pattern in each hole too irregular to permit correlation of zones from one hole to another although this was attempted. However, several generalizations may be made regarding the distribution of zones of high radioactivity:

1. The general trend near the crater center is for gamma radioactivity to increase with depth until a maximum is reached about midway between the shot point and the true crater surface. This pattern becomes less clear with increased distance from the crater center, but the pattern roughly holds true near the true crater surface, as the gamma logs of hole U64c demonstrate.
2. Local zones of high radioactivity occur in the fallback above the zero point. The existence of these was demonstrated in all four of the drill holes. These are apparently local in development and represent inequities in the fallback distribution of fission products ejected from the crater by the explosion.
3. Local high-intensity peaks outside the true crater surface show up in logs from all four of the holes. These narrow zones of substantially higher radioactivity are believed to be caused from the injection of liquid or gaseous fission products into open fractures developed outside the true crater surface.* The drill holes appear to have transected these fractures at nearly right angles as indicated by the intensity of the radioactive peaks and the abruptness of change from background both entering and leaving the fractures.

Data for the gamma ray logs are included in Appendix A.

* An alternate explanation is that pieces of radioactive glass which had fallen down the hole during drilling had become lodged in the hole walls. This is considered unlikely in view of the hole wall characteristics and the drilling techniques used.

LABORATORY RESULTS

The laboratory work consisted of tritium analyses of ten 55-ft composite samples taken from drill hole U64a, and visual and binocular microscope examination of the punch core samples taken from U64a (data summarized in Appendix D).

Tritium Analyses

Preliminary tritium analyses carried out on ten composite samples from drill hole U64a are tabulated in Appendix D, along with a graphical summary of the data. These data indicate that the bulk of the tritium remaining within the fallback lies above the shot point with the relative concentration decreasing rapidly and regularly within the apparent crater with greater depth. This distribution supports the thesis that condensation of initial steam, followed by entrapment of tritiated water by fine particles within material thrown from the crater by the explosion, played a major role in retaining tritium in the fallback material.*

Sample Examination

Punch core samples were examined visually in hand specimens to determine gross characteristics of the alluvium and size distribution of particles. Selected material was examined under a binocular microscope with magnification up to 30 diameters to check for the presence of fragments of explosion-produced glass and to verify the hand specimen observations. Only a very few small pieces of glass were observed in the specimens examined. No further work was done with the glass.

The observations made during the above-described examination of the punch core samples are tabulated in Appendix C.

*See Knox, Joseph B., pp. 23-25. Also, Koranda, John.

SUMMARY AND CONCLUSIONS

The main features of the Sedan crater are shown in Fig. 6. The following are some of the more important conclusions:

1. True crater surface lies approximately 192.4 ft below the original zero point.
2. Tritium is distributed in a regular way throughout the crater fallback, with the majority of the tritium concentrated in the fallback above the zero point.
3. The shape of the true crater surface below the shot point is roughly hemispherical and shows a bellling outward above the shot point towards the surface away from the center of the crater.
4. A zone of compacted fallback of higher density than preshot exists within the crater. This zone is roughly lens-shaped and begins about 50 ft below the shot point. Maximum densities encountered at the base of the compacted fallback are approximately 20% higher than preshot.
5. A zone of compacted alluvium exists outside the true crater surface. This zone exceeds 180 ft in thickness in the region below the zero point and may be 200 ft thick or more. The maximum density increase over preshot near the true crater surface is approximately 15 to 20%, depending on the specific location.
6. Fractures developed in the medium below the true crater boundary probably consist of two major types: (a) concentric rebound fractures formed at the time of cavity pressure release, and (b) radiating fractures formed during the initial expansion phase of the cavity.
7. Punch core samples from different parts of the crater show minor lithologic differences. In general, these differences are not sufficiently distinctive to characterize the part of the crater environs from which the sample was taken. However, differences in degree of disaggregation of cemented alluvium from hole U64a provide evidence for the location of the true crater surface in support of more precise data obtained from geophysical logs.

APPENDIX A
GEOPHYSICAL DRILL HOLE LOG DATA AND INTERPRETATION

U64a (Porta-Drill Hole, located 31.50 ft, S 56°04' E from Ground Zero)

Total hole depth — 692.5 ft

Temperature Log

0 - 390 ft	Regular temperature increase from 99 to 166°F.
390 - 548 ft	High temperature region with a fairly flat, plateau shape to the temperature curve, all above 166°F.
504 ft	Temperature maximum of 169.5°F (suggested cavity boundary).
548 ft	Very sharp temperature decline from 169°F (possible alternate position of true crater surface).
548 - 688 ft	(Bottom of hole) Regular decrease from 169°F to bottom hole temperature of 123°F. Direction of curve movement near the bottom of the hole indicates the temperature is still decreasing.

Gamma Ray Log (Background 1/2 unit)

0 - 138 ft	Irregular radioactivity varying from 4 units to a maximum of 26.5 units. At 138 ft the radiation log begins a steep rise.
138 - 218 ft	Zone of high radioactivity with an average value of about 30 units and a fluctuation of about 3 units. Sharp decrease at 218 ft.
218 - 390 ft	Highly irregular radioactivity readings varying from 2.5 to 35 units. Average intensity of readings decreases with depth. Intensity peaks below about 350 ft are markedly less.
394 - 492 ft	Bottom of last major intensity peak. Irregular radioactivity levels average from 1 to 3 times background.
492 ft	The intensity peak about 8 times background.
492 - 592 ft	Below this peak intensity is moderately irregular with the average between 1 and 2 times background.
592 - 598 ft	Single intensity peak about 5 times average centered at 595 ft. Below 592 ft curve is even and regular at background.
594 - 688 ft	Curve is even and regular. Radioactivity is at or near background levels.

Density Log (Interpreted in conjunction with caliper log)

Log begins at 50-ft depth.

50 - 86 ft	Log irregular. Density between 2.0 and 2.24.
86 - 99 ft	Minimum density (washout).
99 - 130 ft	Irregular between 1.60 and 1.90.

130 - 340 ft	Minimum density (probable irregular washout).
340 - 386 ft	Irregular between 1.75 and 2.08, ascending regularly.
386 - 540 ft	Irregular between 2.0 and 2.25.
540 - 560 ft	Average minimum of 1.83 with sudden decline from 540 ft and gradual increase to 560 ft.
560 - 625 ft	Irregular between 2.00 and 2.10.
625 - 684 ft	(Bottom of hole) Gradual decline from 1.95 to 1.85.
684 ft	(Bottom of hole) Density approximately 1.85.

U64c (Boyles Vertical Drill Hole 143.98 ft, N 70°28'E from Ground Zero)

Total hole depth - 489 ft

Temperature Log

0 - 56 ft	Regular increase from 83 to 89°F.
56 - 98 ft	Equal temperature region at 89°F.
100 - 120 ft	Decrease from 89 to 88°F.
120 - 200 ft	Equal temperature region at 88°F.
200 - 418 ft	Gradual temperature increase from 88 to 100.5°F. Rate of increase becomes increasingly rapid from 350 to 418 ft.
418 - 428 ft	Equal temperature region at 100.5° forming a sharp inflection in the overall rapid increase of temperature with depth in the hole.
428 - 489 ft	(Bottom of hole) Increasing from 100.5 to 135.5°F.

Gamma Ray Log (60K Scale)

(Background in hole as recorded on log is approximately 1/10 gamma ray units.)

20 - 50 ft	Background.
50 - 77 ft	Irregular high readings from 9 to 10 units.
77 - 112 ft	Background.
112 - 188 ft	Irregular high readings. Maximum 19 units, usual high from 5 to 7 units.
188 - 214 ft	Background.
214 - 220 ft	High reading centered at 218 ft of 9 units.
220 - 296 ft	Background.
296 - 376 ft	Irregular high readings. Usual maximums between 17 and 21 units. Intensity of maximum readings decreases slightly with depth.
376 - 400 ft	Background (bottom of 60K scale log).

Gamma Ray Log (20K Scale)

250 - 296 ft	Background
296 - 376 ft	Irregular high readings, mostly off scale.

376 - 398 ft	Background.
398 - 400 ft	Radiation peak about 1.2 units, centered at 398 and surrounded by background of about 1/10 units both above and below.
400 - 488 ft	(Maximum depth shown on log) Background.

Attempts to run density and caliper logs in U64c were unsuccessful because of the caving condition of the uncased hole.

U64e (Boyles 45° Slant-Hole Drilled 61.5 ft, N 88°15'W from Ground Zero)

Total hole depth - 350 ft

Temperature Log

0 - 15 ft	Increase in temperature from 80.5 to 81.5°F.
15 - 30 ft	Equal temperature region at 81.5°F.
30 - 108 ft	Regular decrease in temperature from 81.5 to 76°F.
108 - 150 ft	Equal temperature region at 76°F.
150 - 335 ft	Regular increase in temperature from 76 to 84.5°F.
335 - 350 ft	(Bottom of hole) Equal temperature region at 84.5°F.

Gamma Ray Log (200K Scale - Background approximately 1/2 unit)

11 - 56 ft	Irregular radioactivity with peaks from 3 to 6 units.
56 - 78 ft	Background.
78 - 122 ft	Irregular radioactivity. Maximum peak of 21 units. Most peaks between 9 and 16 units. Intensity decreases with increased depth.
122 - 130 ft	Background.

Gamma Ray Log (20K Scale - Background approximately 1/2 unit)

11 - 54 ft	Irregular radioactivity, mostly off scale.
54 - 78 ft	Irregular radioactivity, near background, varying from 1.5 to 5 units; average about 2.5 units.
78 - 124 ft	Zone of high radioactivity, nearly all off scale.
124 - 166 ft	Irregular radioactivity, near background, varying between 1/2 and 2 units; average about 1 unit.
166 - 170 ft	Peak, approximately 8 units high, centered at 168 ft.
170 - 242 ft	Irregular radioactivity, near background, between 1 and 3 units, with an average of about 1.5 units.
242 - 278 ft	Irregular high radioactivity with one peak off scale.
278 - 328 ft	Irregular low radioactivity, near background, between 1/2 and 2 units, with average of about 1 unit.
328 - 332 ft	Single radioactive peak of about 8 units centered at 330 ft.
332 - 350 ft	(Bottom of hole) Background.

Density Log (Interpreted in conjunction with caliper log)

0 - 90 ft	Hole case.
90 - 190 ft	Hole badly caved giving irregular density readings; highest peak density reading about 2.0.
190 - 240 ft	Caliper log shows hole diameter regularly decreasing from about 17 in. to approximate bit size (6-1/4 in.). Density log irregular with a maximum reading of about 2.1.
238 - 350 ft	Hole size from caliper log stands well with most segments of the hole approximate bit size. Maximum hole size about 8.5 in. Average hole size about 7 in. Maximum density log reading is at 232 ft.
238 - 275 ft	Density log slightly irregular with a maximum of 2.5 and an average of about 2.15.
275 - 311 ft	Density log slightly irregular with a range of about 1.3 to 2.0.
311 - 317 ft	Density log shows marked increase from 1.9 to 2.5.

U64f (Boyles 41°26' Slant-Hole Drilled 149.5 ft, N 69°28'E from Ground Zero

Total hole depth - 250 ft

Temperature Log

0 - 9 ft	Equal temperature region at 76°F.
9 - 22 ft	Regular decrease in temperature from 76 to 70.5°F.
22 - 72 ft	Equal temperature region at 70.5°F.
72 - 95 ft	Irregular decrease from 70.5 to 68°F.
95 - 224 ft	(Bottom of hole) Approximately equal temperature region at about 68°F.

Gamma Ray Log (200 K Scale — Background about 1/4 unit)

0 - 10 ft	Low radioactivity, between 1 and 1.5 units.
10 - 38 ft	Rises and falls from single radioactive peak centered at 29 ft. Maximum reading is 11 units.
38 - 84 ft	Background readings.
84 - 102 ft	Irregular higher radioactivity. Maximum readings 4.5 units.
102 - 130 ft	Background.
130 - 150 ft	Zone of higher radioactivity. Maximum reading about 12 units.
150 - 175 ft	Zone of low radioactivity between 0.5 and 2 units.
175 - 220 ft	(Bottom of hole) Irregular higher readings. Maximum at 184 ft is 13 units. Average throughout zone approximately 9 units.

Tabular Summary of Data from Temperature Logs

Average temperature values were determined for each 10-ft interval as shown below covering the entire depth of all drill holes. Values were determined graphically by Alfred J. Horn. Logs were run at the rate of 30 fpm.

U64a Temperature Log

Depth (ft)	Average temp.(°F)	Depth (ft)	Average temp.(°F)	Depth (ft)	Average temp.(°F)
0- 10	100.5	230-240	138.3	470-480	169.5
10- 20	103.7	240-250	141.3	480-490	169.6
20- 30	107.0	250-260	143.7	490-500	169.7
30- 40	110.0	260-270	146.2	500-510	169.7
40- 50	111.4	270-280	148.2	510-520	169.6
50- 60	112.4	280-290	152.3	520-530	169.6
60- 70	113.5	290-300	155.3	530-540	169.5
70- 80	114.6	300-310	157.0	540-550	167.6
80- 90	115.6	310-320	158.8	550-560	161.0
90-100	116.8	320-330	160.0	560-570	153.0
100-110	118.0	330-340	161.2	570-580	149.7
110-120	118.8	340-350	162.5	580-590	145.3
120-130	120.4	350-360	163.5	590-600	141.8
130-140	121.7	360-370	164.0	600-610	138.0
140-150	123.4	370-380	164.3	610-620	134.2
150-160	124.8	380-390	165.3	620-630	131.0
160-170	125.6	390-400	166.5	630-640	129.6
170-180	126.5	400-410	167.4	640-650	128.2
180-190	128.0	410-420	168.2	650-660	126.5
190-200	129.8	420-430	168.5	660-670	124.8
200-210	131.4	430-440	168.8	670-680	123.8
210-220	133.4	440-450	169.0	680-688	118.0
220-230	135.5	450-460	169.2		
		460-470	169.4		

U64c Temperature Log

Depth (ft)	Average temp.(°F)	Depth (ft)	Average temp.(°F)	Depth (ft)	Average temp.(°F)
0- 10	83.8	160-170	88.2	320-330	91.4
10- 20	85.2	170-180	88.2	330-340	92.0
20- 30	86.3	180-190	88.2	340-350	92.4
30- 40	87.5	190-200	88.2	350-360	92.8
40- 50	88.4	200-210	88.3	360-370	93.6
50- 60	88.8	210-220	88.4	370-380	94.5
60- 70	88.9	220-230	88.6	380-390	95.6
70- 80	88.9	230-240	88.8	390-400	96.9
80- 90	88.9	240-250	89.2	400-410	98.8
90-100	88.9	250-260	89.4	410-420	100.0
100-110	88.6	260-270	89.7	420-430	100.4
110-120	88.3	270-280	90.0	430-440	101.4
120-130	88.2	280-290	90.1	440-450	105.5
130-140	88.2	290-300	90.5	450-460	112.0
140-150	88.2	300-310	90.8	460-470	118.5
150-160	88.2	310-320	91.0	470-480	125.3
				480-489	132.0

U64e Temperature Log

Depth (ft)	Average temp.(°F)	Depth (ft)	Average temp.(°F)	Depth (ft)	Average temp.(°F)
0- 10	81.0	120-130	76.3	240-250	80.3
10- 20	81.6	130-140	76.3	250-260	80.8
20- 30	81.7	140-150	76.4	260-270	81.8
30- 40	81.3	150-160	76.5	270-280	81.6
40- 50	80.8	160-170	76.8	280-290	82.2
50- 60	80.0	170-180	77.1	290-300	82.8
60- 70	79.3	180-190	77.4	300-310	83.3
70- 80	78.5	190-200	77.9	310-320	83.8
80- 90	77.9	200-210	78.4	320-330	84.1
90-100	77.3	210-220	78.8	330-340	84.4
100-110	76.5	220-230	79.3	340-350	84.4
110-120	76.3	230-240	79.8		

U64f Temperature Log

Depth (ft)	Average temp.(°F)	Depth (ft)	Average temp.(°F)	Depth (ft)	Average temp.(°F)
0- 10	76.0	80- 90	69.6	160-170	67.9
10- 20	72.0	90-100	68.2	170-180	67.6
20- 30	70.7	100-110	67.9	180-190	67.2
30- 40	70.5	110-120	67.7	190-200	67.2
40- 50	70.5	120-130	67.7	200-210	67.2
50- 60	70.5	130-140	68.0	210-220	67.2
60- 70	70.5	140-150	68.0	220-224	67.2
70- 80	70.0	150-160	68.0		

Tabular Summary of Data from Gamma Ray Logs

Average gamma values were determined in counts for each 10-ft interval logged. Several holes were logged more than once at different sensitivities. However, data from two logs are included here only in the case of U64e. Values were determined graphically by Alfred J. Horn. All values were read from the logs in scale units and converted to counts. The radiation intensity values recorded from one hole do not necessarily correlate with those from the other holes but are internally consistent on a relative basis throughout a single hole.

U64a Gamma Ray Log

Depth of log, 0 to 687 ft
Speed, 30 fpm
Sensitivity setting, 60K
Tool Model No. 440A

Diameter, 3-5/8 in.
Detector type, G. M.
Detector length, 12 in.
Date run, June 24, 1964

Depth interval (ft)	Average gamma value (10 ³ counts)	Depth interval (ft)	Average gamma value (10 ³ counts)	Depth interval (ft)	Average gamma value (10 ³ counts)
0- 10	5.6	230-240	18.2	460-470	3.5
10- 20	8.4	240-250	15.3	470-480	1.6
20- 30	20.2	250-260	26.2	480-490	1.5
30- 40	21.2	260-270	23.3	490-500	2.6
40- 50	19.6	270-280	19.4	500-510	1.2
50- 60	16.2	280-290	20.0	510-520	0.8
60- 70	9.9	290-300	24.9	520-530	1.3
70- 80	10.2	300-310	26.6	530-540	2.6
80- 90	12.5	310-320	3.6	540-550	1.6
90-100	14.0	320-330	8.2	550-560	2.4
100-110	17.2	330-340	4.0	560-570	2.2
110-120	13.3	340-350	20.7	570-580	0.8
120-130	9.7	350-360	11.0	580-590	0.7
130-140	11.6	360-370	8.3	590-600	2.3
140-150	27.3	370-380	3.2	600-610	0.7
150-160	29.8	380-390	8.8	610-620	0.4
160-170	29.9	390-400	5.6	620-630	0.5
170-180	29.6	400-410	3.2	630-640	0.45
180-190	30.3	410-420	1.8	640-650	0.5
190-200	30.0	420-430	2.6	650-660	0.5
200-210	29.6	430-440	2.0	660-670	0.6
210-220	27.6	440-450	1.0	670-680	0.8
220-230	22.0	450-460	2.5	680-687	3.5

U64c Gamma Ray Log

Depth of log, 20 to 400 ft
Speed, 20 fpm
Sensitivity setting, 60K
Tool Model No. 440

Diameter, 3-5/8 in.
Detector type, G.M.
Detector length, 4 in.
Date run, June 21, 1964

Depth interval (ft)	Average gamma value (10 ³ counts)	Depth interval (ft)	Average gamma value (10 ³ counts)	Depth interval (ft)	Average gamma value (10 ³ counts)
20- 30	0.6	150-160	2.6	280-290	0.6
30- 40	0.4	160-170	15.2	290-300	0.8
40- 50	0.8	170-180	2.8	300-310	13.2
50- 60	11.2	180-190	1.2	310-320	1.2
60- 70	1.4	190-200	0.5	320-330	23.2
70- 80	8.8	200-210	0.6	330-340	34.8
80- 90	0.4	210-220	6.0	340-350	20.0
90-100	0.5	220-230	0.4	350-360	14.0
100-110	0.6	230-240	0.4	360-370	4.0
110-120	1.6	240-250	0.4	370-380	7.0
120-130	1.4	250-260	0.5	380-390	0.4
130-140	2.0	260-270	0.6	390-400	0.4
140-150	4.2	270-280	0.6		

U64e Gamma Ray Log

Depth of log, 10 to 350 ft
Sensitivity settings, 200K and 20K
Date run, June 19, 1964

Depth interval (ft)	Average gamma value (20K) (10 ³ counts)	Average gamma value (200K) (10 ³ counts)	Depth interval (ft)	Average gamma value (20K) (10 ³ counts)
0- 10	—	—	180-190	0.8
10- 20	off scale	4.7	190-200	1.6
20- 30	off scale	5.4	200-210	1.6
30- 40	18.0	2.8	210-220	0.9
40- 50	20.5	2.7	220-230	1.6
50- 60	5.0	1.5	230-240	1.6
60- 70	2.0	0.67	240-250	3.2
70- 80	7.0	0.89	250-260	9.0
80- 90	off scale	11.0	260-270	8.5
90-100	off scale	13.7	270-280	3.4
100-110	off scale	10.5	280-290	1.2
110-120	20.0	7.4	290-300	0.8
120-130	1.7	1.2	300-310	0.7
130-140	1.0		310-320	0.8
140-150	0.65		320-330	1.5
150-160	1.3		330-340	0.7
160-170	3.0		340-350	0.6
170-180	0.9			

U64f Gamma Ray Log

Depth of log, 0 to 220 ft
Speed, 20 fpm
Sensitivity setting, 200K
Tool Model No. 511-A, Type G. M.

Tool diameter, 3-5/8 in.
Detector Model No. 1P7G
Detector length, 4 in.
Date run, June 30, 1964

Depth interval (ft)	Average gamma value (10 ³ counts)	Depth interval (ft)	Average gamma value (10 ³ counts)
0- 10	13	110-120	3.5
10- 20	28	120-130	6
20- 30	70	130-140	27
30- 40	31	140-150	96
40- 50	4	150-160	17
50- 60	3	160-170	11
60- 70	3	170-180	20
70- 80	3	180-190	96
80- 90	6	190-200	92
90-100	23	200-210	93.5
100-110	4.5	210-220	93.5

Tabular Summary of Data from Standard Gamma-Gamma Density Logs

Density values were determined using a standard gamma-gamma density tool in g/cc. No proximity runs were made on any of the holes. The average density values were determined graphically by Alfred J. Horn for each 10-ft logged interval.

U64a Density Log

Logged interval, 50 to 684 ft Tool diameter, 3-5/8 in.
Speed, 20 fpm Tool type, scintillator
Date run, June 24, 1964

Depth interval (ft)	Average bulk density scale reading (g/cc)	Depth interval (ft)	Average bulk density scale reading (g/cc)
50- 60	2.22	540-550	1.89
60- 70	2.095	550-560	1.90
70- 80	2.10	560-570	1.97
80-400	*	570-580	2.04
400-410	2.08	580-590	1.99
410-450	*	590-600	1.98
450-460	2.06	600-610	2.02
460-470	2.10	610-620	2.01
470-480	2.06	620-630	1.97
480-490	2.06	630-640	1.86
490-500	2.10	640-650	1.90
500-510	2.16	650-660	1.86
510-520	2.11	660-670	1.85
520-530	2.03	670-680	1.85
530-540	2.11		

U64c Density Log

Logged interval, 20 to 92 ft Tool diameter, 5-1/2 in.
Speed, 40 fpm Detector type, scintillator
Tool Model No. LAHA Fluid, mud
Date run, June 13, 1964

Depth interval (ft)	Average bulk density scale reading (g/cc)
20-50	*
50-60	1.71
60-70	1.76
70-80	1.72
80-86	1.75
86-92	*

*Data unreliable.

U64e Density Log

Logged interval, 7 to 317 ft
Tool attached to drill pipe;
well logged as pipe was pulled
Davis mix mud in hole

Tool Model No. LAHA
Tool diameter, 5 in.
Detector type, scintillator
Date run, June 6, 1964

<u>Depth interval (ft)</u>	<u>Average bulk density scale reading (g/cc)</u>
7-210	*
210-220	2.0
220-230	2.1
230-240	2.2
240-250	2.15
250-260	2.18
260-270	2.17
270-280	2.15
280-290	1.84
290-300	1.82
300-320	*

U64f Density Log

Logged interval, 50 to 204 ft
Davis mix mud in hole
Tool diameter, 3-5/8 in.
Detector type, G. M.
Date run, June 27, 1964
No proximity run made.

<u>Depth interval (ft)</u>	<u>Average bulk density scale reading (g/cc)</u>
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An attempt was made to log this hole; but
because of poor tool calibration, no usable
data were obtained.

Tabular Summary of Data from Caliper Logs

Average hole diameters were determined for each 10-ft interval from caliper log runs made on holes U64a and U64e. Values were determined graphically by Alfred J. Horn.

U64a Caliper Log

Logged interval, 50 to 684 ft
Hole, dry
Tool Model LEBA
Date run, June 24, 1964

Tool arm diameter, 4 to 34 in.
Tool diameter, 3-5/8 in.
Logging speed, 20 fpm

* Data unreliable.

Depth interval (ft)	Average hole diameter scale reading (in.)	Depth interval (ft)	Average hole diameter scale reading (in.)
50- 60	6.5	260-270	11.4
60- 70	6.7	270-280	9.2
70- 80	6.8	280-290	9.5
80- 90	6.9	290-300	9.6
90-100	8.6	300-310	9.8
100-110	8.6	310-320	11.5
110-120	8.5	320-330	10.5
120-130	9.3	330-340	8.3
130-140	9.0	340-350	11.3
140-150	8.8	350-360	9.3
150-160	8.3	360-370	7.7
160-170	9.0	370-380	7.7
170-180	10.1	380-390	10.0
180-190	14.0	390-400	7.3
190-200	11.7	400-410	7.2
200-210	12.0	410-420	6.7
210-220	12.6	420-430	6.8
220-230	13.5	430-440	6.7
230-240	12.8	440-450	6.6
240-250	14.5	450-684	6.25 or less
250-260	9.4		

U64e Caliper Log

Logged interval, 10 to 349 ft
Hole fluid, mud
Tool Model LEBA

Tool diameter, 3-5/8 in.
Tool arm diameter, 4 to 33 in.
Logging speed, 15 fpm

Date run, June 19, 1964

Depth interval (ft)	Average hole diameter scale reading (in.)	Depth interval (ft)	Average hole diameter scale reading (in.)
10- 20	6.8	180-190	15.6
20- 30	7.2	190-200	10.0
30- 40	6.8	200-210	14.3
40- 50	6.7	210-220	10.0
50- 60	6.7	220-230	8.0
60- 70	6.7	230-240	8.4
70- 80	6.7	240-250	6.6
80- 90	6.7	250-260	7.0
90-100	7.4	260-270	7.3
100-110	13.2	270-280	6.7
110-120	13.2	280-290	6.7
120-130	10.0	290-300	6.0
130-140	10.0	300-310	6.4
140-150	9.2	310-320	6.5
150-160	13.0	320-330	6.25
160-170	15.0	330-340	6.7
170-180	16.0	340-349	7.5

APPENDIX B
PROCEDURE USED IN PREPARATION OF TEN COMPOSITE SAMPLES
FROM DRILL HOLE U64a

Field Sample Recovery Procedure

1. Samples were obtained from a vertical rotary drill hole U64a located 31.50 ft, 556°04'E from ground zero. All depths are measured from the collar elevation. Portions of samples from the upper 550 ft of the hole were combined to form composite samples.
2. Drilling fluid used was Davis Mix which consisted of a water detergent combination mixed with air to form a froth.
3. Samples were recovered by the use of a 2-ft-long punch core which was forced into undisturbed sediment at the bottom of the drill hole and recovered a dry, or nearly dry, sample.
4. Samples taken from the punch core in the field were immediately placed in quart-size, wide-mouth, glass mason jars and tightly sealed with a standard two-piece, screw-type, airtight lid.

Composite Sample Preparation Procedure

1. Samples were placed in an air-conditioned room (controlled temperature at 68°F) for 96 hr to permit temperature equilibrium to be attained.
2. Sample bottles were then opened one at a time, and the appropriate quantity of sample (see chart below) was removed with a stainless steel spoon and transferred to a 250-ml glass bottle with a bakelite screw-type lid. During the sampling procedure, the 250-ml composite sample bottle was placed on a gram scale, pre-set to the desired total weight. Material was then added from the appropriate field sample bottle until the scale was balanced. Each composite sample contains about 200 g and represents 55 ft of vertical hole.
3. All sample bottles were kept closed at all times except when sample transfer was actually taking place. Sample contact with the atmosphere was limited to 60 sec or less.
4. The amount of material added from each field sample to the composite sample was prorated on the basis of the amount of vertical hole represented by each field sample. The chart below summarizes the makeup of the ten composite samples.

SAMPLE NO. 1

<u>Punch core depth (ft)</u>	<u>Grams of sample in composite</u>
5	27.4
10	18.3
15	20.1
21	25.6
29	25.6
35	20.1
40	18.3
45	18.3
50	18.3
55	<u>9.1</u>

Total 201.1 g

Length of sampled interval: 0 to 55 ft.

SAMPLE NO. 2

<u>Punch core depth (ft)</u>	<u>Grams of sample in composite</u>
55	16.4
64	34.7
74	32.9
82	21.9
86	32.0
99.5	<u>63.0</u>

Total 200.9 g

Length of sampled interval: 55 to 110 ft.

SAMPLE NO. 3

<u>Punch core depth (ft)</u>	<u>Grams of sample in composite</u>
111	40.0
121*	00.0
131	54.6
141	54.6
151*	00.0
161	<u>51.0</u>

Total 200.2 g

Length of sampled interval: 110 to 165 ft.

SAMPLE NO. 4

<u>Punch core depth (ft)</u>	<u>Grams of sample in composite</u>
171	40.2
181	73.1
211	<u>87.7</u>

Total 201.0 g

Length of sampled interval: 165 to 220 ft.

SAMPLE NO. 5

<u>Punch core depth (ft)</u>	<u>Grams of sample in composite</u>
221	21.8
231	36.4
241	36.4
251	36.4
261	36.4
271	<u>33.1</u>

Total 200.5 g

Length of sampled interval: 220 to 275 ft.

SAMPLE NO. 6

<u>Punch core depth (ft)</u>	<u>Grams of sample in composite</u>
311	158.5
326	<u>41.5</u>

Total 200.0 g

Length of sampled interval: 275 to 330 ft.

* Not included in composite because punch core was water saturated.

SAMPLE NO. 7

<u>Punch core depth (ft)</u>	<u>Grams of sample in composite</u>
356	122.8
371	<u>77.2</u>
Total 200.0 g	

Length of sampled interval: 330 to 385 ft.

SAMPLE NO. 8

<u>Punch core depth (ft)</u>	<u>Grams of sample in composite</u>
395.5	65.5
410.5	55.5
426.0	<u>79.0</u>

Total 200.0 g

Length of sampled interval: 385 to 440 ft.

SAMPLE NO. 9

<u>Punch core depth (ft)</u>	<u>Grams of sample in composite</u>
440.5	43.6
464.5	57.3
471.0	39.1
486.0	<u>60.0</u>

Total 200.0 g

Length of sampled interval: 440 to 495 ft.

SAMPLE NO. 10

<u>Punch core depth (ft)</u>	<u>Grams of sample in composite</u>
501.0	53.0
518.0	58.5
533.0	<u>89.5</u>

Total 201.0 g

Length of sampled interval: 495 to 550 ft.

APPENDIX C

EXAMINATION OF PUNCH CORE SAMPLES FROM DRILL HOLE U64a*

Degree of disaggregation of cemented alluvium:

A, 0 - 10%	D, 50 - 70%
B, 10 - 30%	E, 70 - 90%
C, 30 - 50%	F, 90 - 100%

Sample depth (ft)	%Clay /silt -1/16mm	% Sand 1/16-2mm	% Small pebbles 2-10mm	% Large pebbles +10mm	Maximum pebble size (cm)	Degree of disaggregation	Amount of water present
5	80	20	—	—	—	E	very dry
Appears like windblown silt and dust. Recovered with the bucket rig from bucket-rig hole A.*							
8	65	15	12	8	—	B	very dry
Recovered with the bucket rig from bucket-rig hole AA.*							
10	50	10	20	20	5	B	very dry
Largest pieces consist of cemented alluvium; small pebbles and smaller are predominantly lithic fragments. Bucket rig hole A.*							
15	50	20	20	10	7	—	very dry
About 75% of the pebble-size pieces are disaggregated alluvium; about 90% of sand and smaller sizes are disaggregated. Bucket rig drill hole AA; similar information from 15 ft sample from bucket rig drill hole A.							
21	57	25	10	8	2	—	very dry
About 50% disaggregated. Bucket rig hole A.							
25	30	10	20	40	5	C	dry
Most large pebbles consist of alluvium aggregates. Bucket rig drill hole AAS.							

*Three attempts were made to drill the hole A near the crater center using a 36 in. - diam. bucket rig. The holes were labeled A, AA, and AAS, respectively. The holes caved and were lost in each case as the result of caving at depths of from 30 to about 90 ft. Several hole stabilization methods were tried, including corrugated steel casing, wetting the sides of the hole with water, and assorted drilling speeds and pressures. When hole AAS was lost at about 90 ft, hole U64a was started nearby using a portadrill and 6 in. casing. Some of the samples recovered from the upper portion of the fallback near the crater center were from holes A, AA, and AAS, as labeled.

Sample depth (ft)	% Clay /silt -1/16mm	% Sand 1/16-2mm	Small pebbles 2-10mm	Large pebbles +10mm	Maximum pebble size (cm)	Degree of disaggregation	Amount of water present
29	50	20	20	10	2	—	very dry
About 50% of pebble-size particles are disaggregated alluvium. Bucket rig hole A.							
30	15	15	20	50	7	C	damp
Bucket rig hole AAS.							
35	20	15	15	40	4	C	damp
Large fragments usually not disaggregated. Bucket rig hole AAS.							
40	20	15	15	40	5	C	damp
Large fragments usually not disaggregated. Bucket rig hole AAS.							
45	30	25	20	25	3	C	damp
Bucket rig hole AAS.							
50	25	25	20	30	4	D	damp
Bucket rig hole AAS.							
50-52	15	25	30	30	4	C	very wet
Portadrill hole*							
55	30	25	25	20	3	C	dry
Bucket rig hole AAS.							
64	30	25	25	20	10**	C	dry
Bucket rig hole AAS.							
74	30	25	25	20	—	D	damp
Bucket rig hole AAS.							
82	30	25	25	20	3	D	dry
Bucket rig hole AAS.							
86	30	25	25	20	4	D	wet
Bucket rig hole AAS.							
99-100	25	20	30	25	4	E	damp
Contains a number of freshly broken limestone pebbles.							

*All further samples are from the portadrill hole unless otherwise noted.

**One only.

Sample depth (ft)	% Clay /silt -1/16mm	% Sand 1/16-2mm	Small pebbles 2-10mm	Large pebbles +10mm	Maximum pebble size (cm)	Degree of disaggregation	Amount of water present
110-112	35	30	20	15	5	D	damp
120-122	10	25	35	30	3	E	very wet
Samples very badly washed; most fines removed.							
130-132	30	25	25	20	3	E	damp
140-142	20	30	30	20	5	C	dry
Marked increase in the relative quantity of disaggregated particles, particularly in the small pebble and sand-size ranges.							
150-152	10	15	25	50	6	E	very wet
Badly washed with drilling fluid. Nearly all small particles removed.							
161	25	25	25	25	7	E	damp
170-172	20	30	30	20	4	C	dry
Noted decrease in amount of disaggregation over previous sample. A damp sample from 170 to 171 ft is also available but was not evaluated.							
180-182	15	20	30	35	5	E	wet
210-212	25	25	25	25	5	E	damp
220-222	20	30	25	20	4	D	damp
230-232	30	35	15	20	4	D	damp
240-242	12	21	27	40	7	C	dry
This sample lacks the large relative quantity of fines present in most other samples and yet is dry, indicating the fines were not washed away by drilling fluids. Also, a much larger percent of the pebble-size pieces are caliche cemented alluvium and a much smaller percent lithic fragments. This sample could be from a preshot alluvium layer well cemented by caliche indicating near-surface origin.							
250-252	20	20	25	35	4	E	wet
260-262	10	20	30	40	4	C	wet
Lumping of finer particles seems to have occurred because of the relatively high water content. This should explain in part the relative lack of disaggregation and the absence of the finer particles.							
270-272	35	35	20	10	2	E	very dry
310-312	30	30	20	20	5	D	dry

Sample depth (ft)	% Clay /silt -1/16mm	% Sand 1/16-2mm	Small pebbles 2-10mm	Large pebbles +10mm	Maximum pebble size (cm)	Degree of disaggre- gation	Amount of water present
570-571	30	15	15	40	5	D	very dry

One large round cobble is present which appears to be about 2/3 the size of a baseball.

574-576	45	20	20	15	5	A	dry
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Most pieces are angular and with markedly different dimensions when measured in different directions. No pebble-size completely disaggregated particles were observed. Appears to be lacustrine deposited loess. Light grayish-tan color, as compared to more buff tan color in 570 to 571 ft sample.

585-587	25	25	25	25	4	A	dry
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Sample consists mainly of angular, nondisaggregated, moderately cemented alluvium. Color is more tan to brown than preceding sample.

600-602	55	20	15	10	3	A	dry
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Appears to be of lacustrine origin. Dust-sized particles predominate.

APPENDIX D

SUMMARY OF RESULTS OF RADIOCHEMICAL ANALYSES

The following table and two figures present a summary of the results of the radiochemical analyses. Table D-I presents tabulated tritium and radiation data, and Figs. D-1 and D-2 give the tritium distribution in contained water and alluvium.

Table D-1. Tabulated tritium and radiation data^a—U64a drill hole composite samples.

Sample no.	Depth below crater bottom (ft)	Alluvium (counts/min/g)	Wt. % H ₂ O	Tritium/g alluvium (μCi)	Tritium/ml H ₂ O total (μCi)	Tritium/ml H ₂ O below 100°C (μCi)	Tritium/ml H ₂ O from 100-500°C (μCi)
1	0-55	2.26×10^4	6.08	$3.24 \times 10^{-1} \pm 4\%$	10.66	$5.31 \pm 1.1\%$	$5.35 \pm 2.5\%$
2	55-110	9.8×10^3	8.9	$4.29 \times 10^{-1} \pm 5.1\%$	9.65	$4.82 \pm 1\%$	$4.83 \pm 12\%$
3	110-165	1.92×10^4	9.42	$3.53 \times 10^{-1} \pm 2.4\%$	7.40	$3.78 \pm 1.5\%$	$3.62 \pm 6.5\%$
4	165-220	2.06×10^4	7.62	$4.61 \times 10^{-1} \pm 2.4\%$	12.0	$6.1 \pm 1.8\%$	$5.9 \pm 13\%$
5	220-275	4.8×10^3	7.34	$3.50 \times 10^{-1} \pm 2\%$	9.01	$4.88 \pm 1\%$	$4.13 \pm 4\%$
6	275-330	7.8×10	5.42	$2.42 \times 10^{-1} \pm 2.9\%$	7.95	$4.72 \pm 0.4\%$	$3.23 \pm 6.2\%$
7	330-385	4.5×10^3	8.5	$9.89 \times 10^{-2} \pm 0.1\%$	2.12	$1.22 \pm 0.4\%$	$0.9 \pm 3\%$
8	385-440	1.44×10^2	6.77	$2.41 \times 10^{-2} \pm 6.1\%$	6.07×10^{-1}	$3.88 \times 10^{-1} \pm 0.1\%$	$2.27 \times 10^{-1} \pm 3.6\%$
9	440-495	3.45×10^2	7.66	$3.59 \times 10^{-3} \text{ }^b$	3.6×10^{-2}	$1.55 \times 10^{-2} \pm 2.3\%$	$2.05 \times 10^{-2} \text{ }^b$
10	495-550	1.64×10^2	5.26	$4.66 \times 10^{-4} \pm 3.7\%$	9.14×10^{-3}	$7.91 \times 10^{-3} \pm 6\%$	$1.23 \times 10^{-3} \pm 7.7\%$

^aResults of gamma radiation in counts per minute per gram of alluvium. The tritium concentration is in microcuries of tritium per gram of alluvium or per milliliter of water. Quoted percent errors are one half the spread between the two individual measurements.

^bOne measurement.

Fig. D-1. Tritium distribution in contained water from Sedan composite samples.

Fig. D-2. Tritium distribution in alluvium from Sedan composite samples.

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