

VOLCANIC HISTORY OF THE GREAT RIFT,
CRATERS OF THE MOON NATIONAL MONUMENT, SOUTH-CENTRAL IDAHO

A Summary Report of the Investigations in 1969 and 1970

by

Fred M. Bullard

INTRODUCTION

Craters of the Moon National Monument is located in the eastern part of the Snake River lava plain in southern Idaho. It represents an area of cinder cones and lava flows associated with a fissure-type eruption from the Great Rift, a S.E. trending fracture zone extending from the Pioneer Mountains through the Craters of the Moon and across the Snake River Pleistocene lava plain to Crystal Ice Cave, a distance of about 48 miles. The primary objective of the study was to determine the eruptive history of the Great Rift and to contribute to a better understanding of the volcanic history of the Craters of the Moon National Monument area. Very few fissure-type eruptions have occurred in historic times and our knowledge of the nature of such eruptions is limited. The eruptions from the Great Rift are among the most recent eruptions of this type known and it was hoped that this study would contribute to a better understanding of fissure-type eruptions. A more detailed statement of the objectives of the study is contained in the Research

Proposals for 1969 and 1970. The work was supported by grants from the Craters of the Moon Natural History Association and for the summer of 1970 a supplementary grant from the Geology Foundation of the University of Texas.

The field work during the summer of 1969 was done by Mr. Don Rylander, graduate student at the University of Texas, under the supervision of the writer. Mr. Rylander plans on submitting the results of his studies for a Master's thesis in geology at the University of Texas. During the summer of 1970 the writer was assisted by Mr. Jerry Gips, graduate student in geology at the University of Texas. Laboratory facilities at the University of Texas at Austin were used for the study of the rock samples and for the radio-metric age determinations.

The results of the work done during the summer of 1969 were reported to the Superintendent of the Craters of the Moon National Monument in the "Investigator's Annual Report" under date of Jan. 15, 1970. The results for the 1970 field season were similarly reported under date of Dec. 15, 1970. Copies of these reports are attached as Appendix A. The results of the 1969 field season were also reported in a joint paper (with Don Rylander) at the South-Central Section Meeting of the Geological Society of America, College Station, Texas, on April 2, 1970. An abstract of this paper, as published in the Proceeding of the Society, entitled: "Holocene Volcanism in Craters of the Moon National Mounument and Adjacent Areas, South-Central Idaho," is included as Appendix B. Some of the

results of the 1970 field season were reported by the writer in a paper at the annual meeting of the South-Central Section of the Geological Society of America at Lubbock, Texas, on March 25, 1971. An abstract of the paper, as published in the Proceeding of the Society, entitled: "Volcanic History of the Great Rift, Craters of the Moon National Monument, South-Central Idaho," is included as Appendix C.

A summary of the results previously reported as well as additional material is included in this paper.

THE RESULTS OF THE STUDY

Not all the objectives, as outlined in the two research proposals attached, were achieved. Indeed, it was not anticipated that all of the objectives listed could be studied in the time available. Instead, certain priorities were established and the work was centered on these objectives.

I felt that the most pressing needs were: (1) an accurate map of the Great Rift system with studies to determine the extent and relative displacement of the individual fractures, (2) the extent and volume of material erupted from the Great Rift, and (3) the age or dating of the volcanic activity from the Great Rift. Many other aspects of the volcanic activity in the area were studied but additional work must be done before conclusive results can be presented. Nevertheless, comments on a number of these items will be included as (4) Miscellaneous observations. The results of our studies on the above topics, which I feel are sufficiently complete to warrant reporting, are covered in the following pages under the appropriate heading.

1. The Great Rift

(To be submitted later)

2. Volume and extent of the material erupted from the Great Rift.

The early eruptions from the Great Rift in the Craters of the Moon area produced largely pyroclastic material followed by numerous basaltic lava flows which spread in sheets and tongues up to 28 miles to the southwest and 13 miles to the northeast. The entire area is covered by U. S. Army 1-60,000 aerial photographic coverage of some limited areas on a scale of 1-20,000. The U. S. Bureau of Land Management base maps (compiled in part from aerial photographs) are also available.

Using the U. S. Department of Agriculture photo coverage as a base, the extent of the lava flows from the Great Rift were mapped and field checked. The U. S. Army and the U. S. Bureau of Land Management maps were used to fill in areas not covered by the U. S. Department of Agriculture photos. The total area covered by lava flows from the Great Rift is 600 sq. miles. At Crystal Ice Cave area, at the southeastern end of the Great Rift, the lava field covers only 1.1 sq. miles.

In order to estimate the volume of lava produced by eruptions from the Great Rift certain assumptions had to be made as to the thickness of the lava. At the margins of the lava fields the flows (single flows) are around 25 feet in thickness. However, near the Great Rift many flows are superimposed and the thickness is many times greater. This is apparent, even on the topographic map of the Craters of the Moon National Monument which shows the surface rising as the Rift is approached. Taking into account all the information

available a thickness of 155 feet for the lava at the Great Rift was reached. It is my feeling that this is a conservative estimate. Further, some subsidence is common in areas where large volumes of lava are erupted but in this calculation no allowance was made for subsidence. A total volume of lava of nine cubic miles was erupted from the Great Rift, based on the assumptions as to thickness stated above. Further, this does not include pyroclastic material, except insofar as it is interbedded with the lava. Unquestionably, much of the finer particles were carried a considerable distance by the wind and do not enter into our calculations. It would appear, therefore, that the figure of nine cubic miles is a conservative one.

3. Age of Volcanic activity

The freshness and barrenness of the black lavas in Craters of the Moon National Monument impress all who view it. Indeed, for many the first impression is that it cannot be very old and might still be hot in places! The conclusion as to age, as stated by Russell in 1902 (p. 105) is typical:

"Although it is impossible to make a well founded estimate of the time that has elapsed since the last eruption, it seems probable that it is no more than 100 or possible 150 years."

It soon became apparent that Russell had missed the age by a wide margin since tree ring counts established the fact that trees growing in cracks in the lava were several hundreds of years old. The most reliable estimate of the age of the lava flows, prior to the results reported in this paper, was based on the number of growth rings in a tree growing in a crevass in a lava flow from North Crater. This flow is believed to have been one of the last lava flows in the area. Stearns, 1963 (p. 27) comments on the age of the lava flows as follows:

"The Triple Twist Tree growing out of a crack in the North Crater flow died in 1961 with a rotted heart. A core 16 1/2 inches long removed from this tree by the Park Service in 1954 had 1350 years of growth as determined by a count of the annual rings by the Laboratory of Tree Ring Research at the University of Arizona. It is estimated that the tree is about 1500 years old allowing for the missing heartwood. This means that the lava is at least 1650 years old, if time is allowed for the lava to cool and soil to accumulate. The flow may be several times this old."

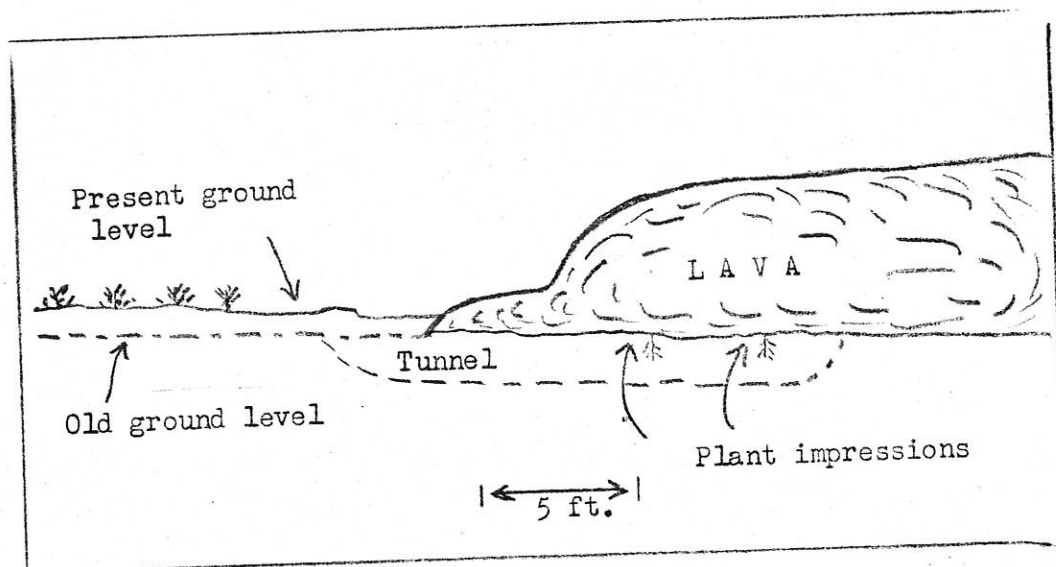
As will be apparent from the radiocarbon dates presented later in this paper, the tree ring count was in rather close agree-

ment with the actual age.

The area seemed particularly suitable for age determinations by the radiocarbon method, providing samples of charcoal or charred wood could be obtained. It seemed quite possible that the lava flows had buried trees or shrubs and that fragments of charcoal might still be present. The fact that numerous tree molds were present in the area was ample evidence that trees were growing in the area at the time of some of the eruptions. Nevertheless, a careful search of the tree mold areas did not uncover any charcoal fragments. Apparently, all charcoal fragments which were exposed had been destroyed by weathering in the several hundreds of years since the last eruption. The solution, it seemed, was to locate vegetation which had been killed by the lava flow and which was still protected from weathering. This might be done by tunneling beneath the lava flow where the carbonized rootlets of the shrubs killed by the advancing lava were, hopefully, still intact.

After deciding to tunnel beneath the flow there were several factors to be taken into account in selecting a site for the "dig." In the first place the selected site must have a sufficient soil layer on the older lava surface over which the lava was advancing to support a growth of vegetation. Further, it was essential that the margin of the flow be relatively free of alluvial fill. In many cases when the lava comes to rest it forms a "dam" which traps the sediment washed from the adjacent area and the lava front may be buried under many feet of alluvial "fill" making it difficult or in some cases impossible to reach the base of the lava flow with ordinary hand

tools. With these points in mind Don Rylander selected a site on the eastern margin of the Craters of the Moon lava fields and outside the boundary of the Monument. The site was in the North-central part of Section 3, T2S, R27, about 13 miles south of Arco. Here the bedrock is the older Snake River lavas which have a fairly well developed soil horizon and further, the area is removed from the mountain front so alluvial fill would be minimal. The details of the "dig" are shown in the following sketch:



The lava flow beneath which the carbon was obtained, is a well developed pahoehoe type which issued from the Great Rift in the vicinity of Black Tail, some three miles to the west. The lava front at the immediate site of the tunnel was about ten feet thick but in a short distance it increased to 20 to 30 feet. A pahoehoe flow which spreads forward as a fluid layer will cover the existing vegetation and form a smooth, dense, impervious base which will protect the carbonized root-lets from decay. These conditions are not obtained in an "aa" flow which advances over the surface as a rubbly mass. At the

base of a lava front, in many cases, is a collection of rubble made up of blocks of lava which rolled from the lava front as the flow slowly came to rest. This is especially true of "aa" flows and to a lesser extent of pahoehoe flows. In many instances the rubble at the base of a flow is so extensive that it is difficult (even impossible) to reach the base of the main lava sheet.

In the site excavated by Don Rylander there was a minimum of rubble and only about two feet of "fill." The soil layer, about 24 inches in thickness, was relatively easy to excavate. A tunnel about 48 inches in diameter was extended beneath the lava for some 15 to 20 feet. The lower surface of the lava flow was smooth and reflected the surface over which it flowed. The imprint of shrubs (appeared to be sage brush) were clearly visible on the basal surface of the lava. The soil collected from beneath these "brush impressions" contained tiny carbonized rootlets. The soil was carefully collected and spread on a level surface (a sheet of plywood) near the entrance to the tunnel. Here with the aid of a hand lens and tweezers the tiny carbonized rootlets were carefully collected. Some of the rootlets were a dull black color while others were shiny (like anthracite) black. Samples of each were collected but the age determinations were not significantly different. Sage brush growing on the old Snake River lavas today are spaced some three to four feet apart. There is then, some element of chance in the number of "bushes" one would encounter in a given tunnel; we were fortunate in encountering several so enough material for two reliable samples

for radiocarbon age determinations were obtained.

The results were as follows:

Tx. 899		2110	$\pm$ 90	years B.P.
Tx. 900		2050	$\pm$ 80	years B.P.

The first sample (Tx. 899) was the dull charcoal rootlets while Tx. 900 was the shiny, anthracite-like rootlets. [Note: The numbers refer to the permanent file number of the sample at the University of Texas Radiocarbon Laboratory.] These two samples, when averaged, give an age of 2080 ± 85 years, which we consider to be a valid date for the lava flow. While it is not possible to determine whether this flow is the "last" eruption from the Great Rift, it does seem safe to say that it was at least late in the volcanic activity from the Great Rift. Two other age determinations were made from material collected at this site. In each case we were aware that there was some soil contaminations and that the age would not agree with that obtained from the more reliable samples. Nevertheless, we felt that the results would be useful in evaluating future samples. The results are reported here as a matter of record:

Sample Tx. 901 was a concentrate of the residue from the two previous samples after most of the visible carbonized rootlets had been picked out. This material gave an age of 2200 ± 130 years. The second sample, Tx. 902, was from the black soil in which the carbonized rootlets were found. It gave an age of 4420 ± 70 years. In each case the degree of contamination is reflected in the older age for the sample.

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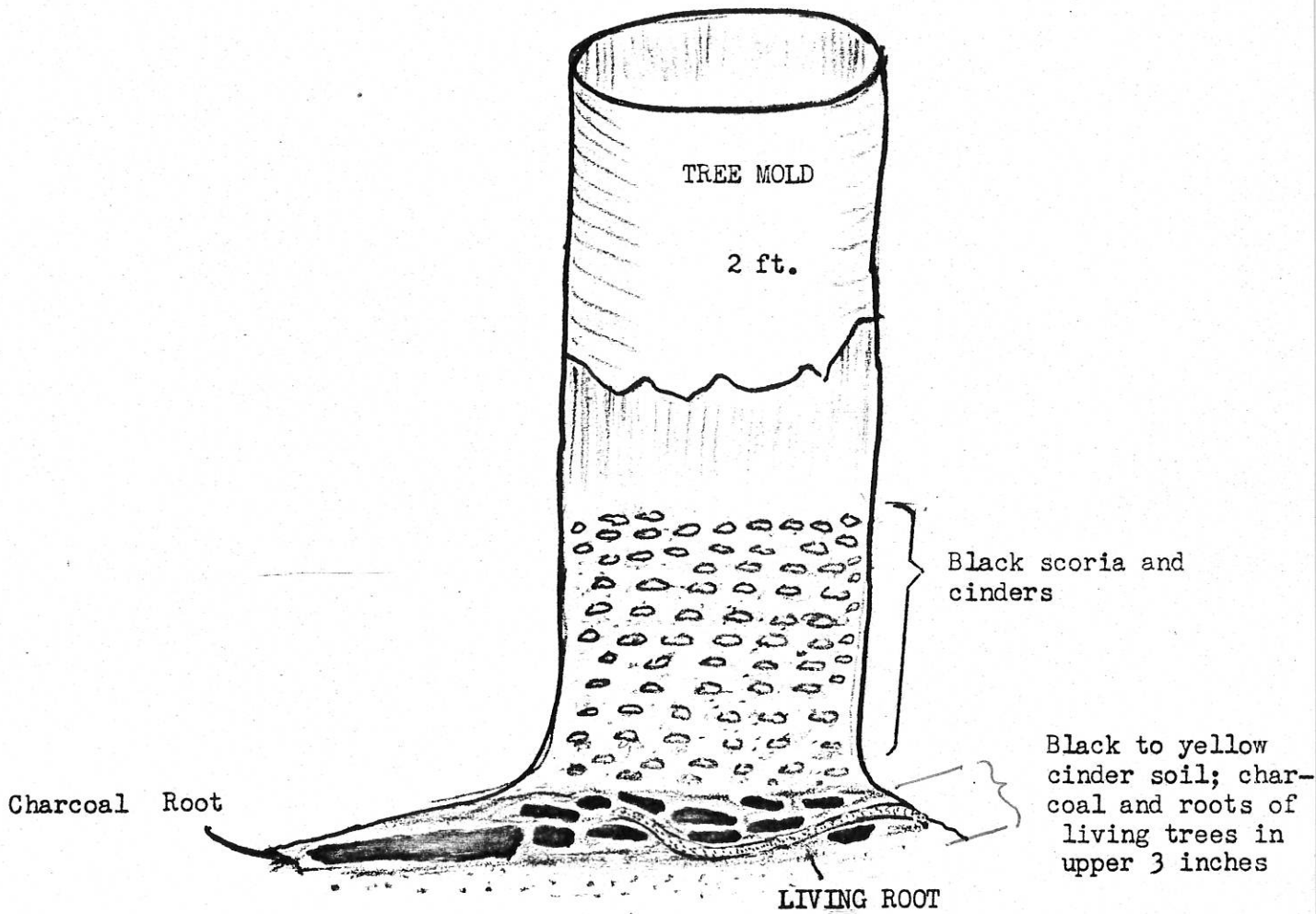
TUNNELING EFFORTS IN 1970. An effort was made to obtain carbon samples from some of the early flows by tunneling beneath the lava, using our experience in 1969 as a guide. "Digs" were made at four locations but in only one were we able to get under the flow and here the amount of carbon recovered was insufficient for a reliable sample. Unsuccessful attempts to tunnel under the older flows were made on Cottonwood Creek, four miles to the northwest of the Visitor's Center; on Lava Creek 4 1/2 miles to the northeast of the Visitor's Center; and at a site about 1/4 mile to the south of the Arco highway, ten miles to the northeast of the Visitor's Center. At each of these sites debris from the mountain front to the north had buried the base of the flow and this "fill" mixed with blocks from the lava front, could not be removed with simple hand tools. This thick fill is, in itself, evidence of the old age of these flows.

The site where we were able to "get under" the lava was near Saddle Butte on the eastern edge of the Craters of the Moon lava field, 13 miles south of Arco. This site is approximately ten miles to the north of the 1969 carbon site. The site does not face the mountain front and only about three feet of "fill" was encountered. After tunneling for about ten feet under the flow and finding only traces of charcoal the effort was suspended. The tunnel was left intact with the thought that further exploration might be done at this site.

CARBON FROM TREE MOLDS. Tree molds along the Great Rift were formed by some of the last eruptions from the Great Rift. Although we had searched without success, for charcoal associated with the tree molds during the 1969 season, we felt that charcoal might be preserved at the base of the trunk or in the root system where the material would have been protected from weathering. The locality selected for this test was Trench Mortar Flat, an area roughly 0.5 x 1 mile, 3.5 miles southeast of the Visitor's Center. Here the west trace of the Great Rift is a trench up to 15 feet deep and 10 to 20 feet wide, with the sides bordered by ramparts of spatter. Prior to the last eruption Trench Mortar Flat was dotted with Limber pine trees. In one of the last eruptions from the Great Rift a flow of highly fluid, scoriaceous lava, from fountains along the Great Rift covered Trench Mortar Flat. The base of the trees, near the Great Rift, were buried by lava and the trunk and lower branches plastered with spatter, forming tree molds (locally known as Lava trees). The upper part of the tree and a portion of the trunk encased in lava doubtless burned quickly. However, the absence of oxygen at the base of the trunk and in the root system resulted in the wood being carbonized.

The average diameter of the 81 tree molds mapped at Trench Mortar Flat was 14.4 inches with a maximum of three feet. Charcoal was obtained from five of the tree molds, with ages ranging from 2130 to 2310 $\pm$ 80 years. The charcoal was limited mainly to the roots embedded in the old soil and in some cases, as in our Sample No.1, the quantity was large, i.e. measured in gallons with root sections up to three inches in diameter. It was interesting to note that trees living in the area today are supported by roots in the same soil horizon as the tree mold roots. In some cases living roots were intertwined with the charcoal roots, presenting a possible source of contamination. In some of the tree molds the amount of charcoal was limited but still adequate for age determinations. All of the tree molds yielding charcoal were adjacent to the Great Rift and the charcoal was limited to the base of the trunk and the root system. In most cases the diameter of the tree mold was too small to permit a person to excavate inside the mold. However, in several of the tree molds immediately adjacent to the Rift, the basal part of the mold was accessible. In such cases a basal section of the tree mold was removed, exposing the base of the trunk and the root section. An idealized cross section of our tree mold No. 1 is included as Figure 1.(following page)

One of the larger tree molds, with a diameter of three feet, we excavated by descending inside the mold. About eight feet of coarse cinders were removed to reach the base of the trunk and although the root system was carefully explored no



IDEALIZED CROSS-SECTION OF TREE MOLD NO. 1, TRENCH MORTAR FLAT, CRATER OF THE MOON NATIONAL MONUMENT, IDAHO.

Fig. 1

76.
significant amount of charcoal was found. However, at the base of the trunk the charred axis of a pine cone was recovered which Seasonal Naturalist Karl Urban identified as the cone of a Limber pine. The jaw bone and other bone fragments of a small rodent were also recovered from this site.

With the assistance of Seasonal Naturalist Karl Urban charcoal was obtained from a tree mold near the base of The Watchman, three miles to the southeast of Trench Mortar Flat. The mold was in a typical pahoehoe flow, about 200 yards from the northwestern base of The Watchman. The tree mold had a diameter of about 31 inches and there was about one foot of cinders and debris covering the charcoal level. Radiocarbon dating of charcoal from this tree mold gave an age of 2140 $\pm$ 60 years.

Samples of charcoal from roots beneath a lava flow at the entrance to Crystal Ice Cave were collected through the courtesy and with the assistance of Mr. James L. Papadakis, President of Crystal Ice Caves Inc. Crystal Ice Cave is 26 miles to the southeast of Trench Mortar Flat and at the southern end of the Great Rift. The two samples gave ages of 2090 $\pm$ 470 years and 2360 $\pm$ 150 years.

17.

17.

Preliminary

SELECTED REFERENCES

Russell, I.C. Geology and water resources of the Snake River Plains of Idaho: U.S.Geol. Survey Bull. 199. 1902

Stearns, H.T., Crandall, Lynn, and Steward, W.G., Geology and groundwater resources of the Snake River Plain in Southeastern Idaho: U.S.Geol. Survey Water Supply Paper 774, 1938

Stearns, H.T. Geology of the Craters of the Moon National Monument, Idaho: Arco, Idaho, Craters of the Moon Natural History Association, 1963.

Papadakis, James, Crystal Ice Caves: SSA Speleologist, vol. 2, Feb. 1968,

INVESTIGATOR'S ANNUAL REPORT
(Natural Sciences Research)

1969

This form is to be completed by the researcher and returned to the Superintendent of the Park by JANUARY 1. See reverse for additional instructions.

TO SUPERINTENDENT	PARK CRATERS OF THE MOON NATIONAL MONUMENT	REGION WESTERN
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1. Project Title

A Study of the Great Rift in Craters of the Moon National Monument & Southeastward

2. Name(s) of Researcher(s) and Institution(s)

Dr. Fred M. Bullard
The University of Texas at Austin

3. Source(s) and Amount(s) of Funds Other Than NPS, if Any

Craters of the Moon Natural History Association -

4. Starting Date of Project January 1969	5. Percent Completion of Project to Date: 75 %	6. Est. Additional Time Required for Completion Beyond January 1st: Years 6 Months
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7. Summary: (a) of progress; (b) of significant findings, if any, to date; (c) recommendations regarding future course, i.e., on basis of work so far, should it proceed as planned, be reoriented, expanded, reduced, time schedule and support level adjusted, etc.;

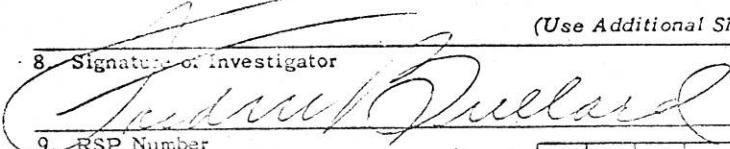
(a) Progress:

Field work on the project was initiated on June 14, 1969 when Don Rylander, my research assistant, arrived at Craters of the Moon, to begin a three month field study. I arrived at Craters of the Moon on June 17, after a stop at the office of U. S. Department of Agriculture in Salt Lake City to select aerial photographs needed for the work. I spent four weeks in the field making preliminary investigations and outlining the objectives for the summer's work. These objectives were: (1) to map the Great Rift throughout its extent and to study the nature of the displacement (if any) along it; (2) to determine the volume of material produced by eruptions from the Great Rift (which required mapping of the lava fields); and (3) to determine the age of the eruptions. All of these objectives were accomplished although additional work is needed on numbers 1 and 3. I felt that detailed mapping of individual flows should be delayed until the objectives listed above were completed. I returned to Craters of the Moon for one week late in August to check on various aspects of the field work.

On our return to the University of Texas in September, we continued work on the project as follows:

- (1) Compilation and final drafting of the maps
- (2) Laboratory study of the rock samples; 30 thin-sections were prepared and they are now being studied microscopically.

(Use Additional Sheets if Necessary)

8. Signature of Investigator 	Date Jan. 15, 1970
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9. RSP Number

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1969

- (3) Four samples of carbon obtained at Craters of the Moon were analyzed in the Radiocarbon Laboratory of the University of Texas to determine the age.
- (4) Work is underway on the preparation of a final report.

(b) Summary of results (to date):

Computations on the volume of material produced from the Great Rift are still in progress; similarly studies on the displacement along the Great Rift are not finished. However, the following summary is pertinent:

The lava fields and subordinate cinder and spatter cones in Craters of the Moon National Monument are the products of fissure-type eruptions from the Great Rift. The Great Rift extends from the Pioneer Mountains southeastward through the Craters of the Moon area and across the Snake River Pleistocene lava plain to the King's Bowl area, a distance of about 48 miles. The Great Rift is a series of en echelon fissures in a zone up to two miles in width. The individual fissures have only minor horizontal and vertical displacements.

The early eruptions from the Great Rift in the Craters of the Moon area produced largely pyroclastics, followed by numerous basaltic lava flows which spread in sheets and tongues up to 28 miles to the southwest of the Rift and 13 miles to the northeast, covering an area of about 600 square miles. The thickness varies from around 20 feet at the margin to approximately 200 feet near the Rift where many flows are superimposed. Several of the flows contain gneissic xenoliths. Lava tubes, varying from two feet or less up to tens of feet in diameter occur in many of the flows.

In the King's Bowl area, at the southeastern end of the Great Rift, the lava field covers only 1.1 square miles.

Charcoal rootlets of plants buried by the lava were obtained by tunneling under the flows. Samples for radiocarbon dates, collected in the north-central part of Sec. 3, T.2 S., R.27 E., gave an age of 2080 ± 85 years B.P. This date does not represent the earliest or the latest activity, but is the date of a flow which is believed to have occurred late in the volcanic history of the area.

1969

(e) Recommendations:

On the basis of the results obtained to date it seems apparent that the project should be continued. Some of the problems which need attention are listed below. In some cases they represent a continuation of last summer's work while others are new projects.

1. The age determinations on three of the four carbon samples were closely grouped and indicate a valid date. However, the flow which produced the carbon for the samples did not represent the oldest or the youngest activity. Additional work (including mapping of some of the flows) must be done to determine the earliest as well as the latest activity. One of the objectives for future work would be to determine the span of time involved in eruptions at Craters of the Moon and also the time-sequence of eruptive activity along the Great Rift.
2. Mapping several of the individual flows and further studies to clarify the history of the "monoliths" carried by some of the flows would provide useful information.
3. The xenoliths, previously known only from the Serrate flow, have been found in other flows. These fragments, carried upward from the underlying basement rocks provide valuable information on the history of the Great Rift. Some of these fragments are now being studied but more extensive collections are needed for comparison with outcrops of basement rocks in adjacent areas.
4. The blue surfaces on some of the Craters of the Moon lava flows, such as the Blue Dragon flow, is a unique feature. Many lavas develop bluish surfaces but I know of nothing comparable to those at Craters of the Moon. Preliminary observations indicate that such surfaces are developed at the margin of many flows where a tongue of lava is squeezed out from beneath an overlying crust. Further, some unusual lava surfaces, such as the broken pahoehoe developing into Aa, are exhibited at Craters of the Moon. A study of these and related features would be a contribution to volcanology.
5. The conditions under which lava tubes develop is not well understood. There are many well developed lava tubes at Craters of the Moon and a critical study of these tubes would certainly contribute to our knowledge of these features.
6. Detailed mapping of the individual lava flows produced from the Great Rift is necessary for a full understanding of the history of the area. The northern part of the Craters of the Moon has been mapped (although some revision is needed) but in the southern part of the area only reconnaissance mapping has been done.

1969

7. Finally, it should be understood that the volcanic activity at Craters of the Moon is the final episode in a long volcanic history which included eruptions of rhyolitic material (including pumice) such as is now exposed at Big Southern Butte and elsewhere. Studies of this earlier activity is difficult because much of the material is now buried by later lavas. Nevertheless, this phase of volcanism is an important part of the history of the area and should be investigated.

RECOMMENDATION:

I recommend that the project be continued for a minimum of two more years (summers of 1970 and 1971). I suggest that the plan followed in 1969 be continued. That is, certain objectives be selected for the summer's work and an effort made to complete the study of those chosen. Thus, various units of the research project would be completed as the program progressed, or in other words each summer is more or less an independent unit.

1970

INVESTIGATOR'S ANNUAL REPORT
(Natural Sciences Research)

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TO SUPERINTENDENT	PARK CRATERS OF THE MOON NATIONAL MONUMENT	REGION PACIFIC NW
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1. Project Title

A Study of the Great Rift in Craters of the Moon National Monument & Southeastward

2. Name(s) of Researcher(s) and Institution(s)

Dr. Fred M. Bullard
The University of Texas at Austin

3. Source(s) and Amount(s) of Funds Other Than NPS, if Any

Craters of the Moon Natural History Association --

4. Starting Date of Project January 1969	5. Percent Completion of Project to Date: 50 %	6. Est. Additional Time Required for Completion Beyond January 1st: 2 ~~years~~ (Summers) Months
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7. Summary: (a) of progress; (b) of significant findings, if any, to date; (c) recommendations regarding future course, i.e., on basis of work so far, should it proceed as planned, be reoriented, expanded, reduced, time schedule and support level adjusted, etc.;

(a) FIELD WORK: Field studies for the 1970 season began on July 1 and continued through August 7. For the last 4 weeks of the period I was assisted by Jerry Gips, a graduate student in geology from the University of Texas.

(b) SUMMER OBJECTIVES: The primary objectives established for the summer's work were as follows: (1) to check on the source of the lava flow from which the carbon samples were obtained during the summer of 1969. (2) To obtain additional carbon samples, hopefully adjacent to the Great Rift, to establish a date for the most recent activity along the Great Rift. (3) To obtain carbon samples from an early flow (preferably from the first one) in order to establish a date for the beginning of volcanic activity along the Great Rift. Secondary objectives included further studies of the xenoliths in the Serrate and other flows; the distribution and origin of the "blue lavas"; distribution and development of lava tubes, etc.

(c) SUMMARY OF RESULTS: (necessarily preliminary since laboratory studies have not been completed). Objectives 1 and 2, as stated above, were accomplished, and some progress was made on Objective 3. Additional data were collected on the secondary objectives.

Objective No. 1. During the summer of 1969 we obtained carbon by tunneling under a flow and collecting charcoal from the roots of shrubs

(Use Additional Sheets if Necessary)

8. Signature of Investigator	Date December 15, 1970
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9. RSP Number

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covered by the lava. The flow from which the samples were obtained is the north-central part of Sec. 3, T.2 S., R. 27 E. This site is along the eastern edge of the Craters of the Moon lava fields and outside the boundaries of the Monument. Radiocarbon age determinations for the two samples considered to be the most reliable gave an average of 2080 ± 85 years B.P. We felt that this flow occurred late in the volcanic history of the area but we could not determine if it was one of the "last" flows. We were also uncertain as to the exact source of the flow. Field studies during the summer of 1970, aided by two overlights in a small plane, convinced us that the flow was from the Great Rift in the vicinity of Black Tail.

Objective No. 2. Tree molds along the Great Rift were formed by some of the last eruptions from the Great Rift. If charcoal could be obtained from the tree molds a radio carbon date would provide the information needed for Objective No. 2. The area selected for this test was Trench Mortar Flat, roughly 3 miles southeast of the Visitor's Center. Here there are numerous tree molds (lava trees) in a belt 0.5 x 1 mile, in and along the east side of the Great Rift. The average diameter of 81 tree molds mapped in this area was 14.4 inches with a maximum of 3 feet. Of the 5 tree molds sampled four yielded significant amounts of charcoal. All of those yielding charcoal were adjacent to the Rift and the charcoal was limited to the base of the trunk and to the root system of the tree mold. The trunk of the largest tree mold excavated, with a diameter of 3 feet, was filled with 8 feet of coarse cinders and yielded no significant amount of charcoal. However, at the base of the trunk the charred axis of a pine cone was recovered which Seasonal-Naturalist Karl Urban identified as the cone of a Limber Pine. A jaw bone and other bone fragments of a small rodent were also recovered from this site. These bones are now being examined by paleontologists at the University of Texas. Radiocarbon age determinations for two of the samples from Trench Mortar Flat gave the following: 2240 ± 80 years B.P. and 2270 ± 80 years B.P. The remaining samples from Trench Mortar Flat are now being processed.

With the assistance of Seasonal-Naturalist Karl Urban charcoal was obtained from a tree mold in a pahoehoe flow near the base of The Watchman, 3 miles to the southeast of Trench Mortar Flat. Radiocarbon dating of this sample gave an age of 2140 ± 60 years.

Samples of charcoal from roots beneath a lava flow at the entrance to Crystal Ice Cave (King's Bowl) were collected through the courtesy and with the assistance of Mr. James L. Papadakis, President of Crystal Ice Cave Inc. Two samples, which were obtained from this site are now being processed and the results will be included in the final report.

Objective No. 3. An effort was made to obtain carbon samples from some of the early flows by tunneling beneath the lava, using our experience in 1969 as a guide. "Digs" were made at four locations but in only one were we able to get under the flow and here the amount of carbon recovered was insufficient for a reliable sample. Unsuccessful attempts to tunnel under the older flows were made on Cottonwood Creek, 4 miles to the northwest of the Visitor's Center; on Lava Creek 4 1/2 miles to the northeast of the Visitor's Center; and at a site about 1/4 mile to the south of the Arco highway, 10 miles to the northeast of the Visitor's Center. At each of these sites debris from the mountain front to the north had buried the base of the flow and this "fill", mixed with blocks from the lava front, could not be removed with simple hand tools. This thick fill is, in itself, evidence of the old age of these flows. Although no carbon samples were obtained from these flows they do have, in many places, a thick coating of caliche (CaCO_3). Techniques have been developed which make it possible to date the caliche (i.e. the carbon in the caliche) by radiocarbon methods. Samples of caliche from several flows were collected and these samples are now being processed. As a check on the results, a sample of caliche from one of the tree molds in Trench Mortar Flat from which charcoal was also obtained will be dated and the results compared.

The site where we were able to "get under" the lava was near Saddle Butte on the eastern edge of the Craters of the Moon lava field, 13 miles south of Arco. This site is approximately 10 miles to the north of the 1969 carbon site. The site does not face the mountain front and only about 3 feet of "fill" was encountered. After tunneling for about 10 feet under the flow and finding only traces of charcoal the effort was suspended. The tunnel was left intact with the thought that further exploration might be done at this site.

Secondary Objectives: Additional collections of zenoliths in the Serrate flow were made. In an effort to determine the abundance of the zenoliths in the Serrate flow I made a traverse of the flow with the assistance of Jerry Gips and Seasonal-Naturalist M'ryka Beyer. The three of us, all trained in geology, were able to locate, measure and describe 26 occurrences in a three hour period. All of the zenoliths consisted of gneissic material, mostly tabular fragments one to three inches long. One striking exception was a huge mass 9 x 12 inches with a thickness of 6 inches. Microscopic studies of the zenoliths, which was started on material collected in 1969 is continuing. In addition, a Potassium-Argon age determination is being run on a sample from the large zenolith.

Gneissic xenoliths were also identified in blocks on the floor of North Crater. Two additional types of xenoliths, not previously reported, were found at North Crater. Masses of a brownish pumice-like material are fairly common in the spatter on the walls of the crater and in blocks on the crater floor. On the east rim of the crater two xenoliths of pink rhyolite were found. The above determinations, based on a megascopic examination, are provisional pending a microscopic study of the material.

Additional samples of the "blue" lava were collected and studies are continuing in an effort to provide a better understanding of this unusual lava.

NOTE: An abstract of a paper to be presented at the 1971 Spring Meeting of the South-Central section of the Geological Society of America is attached.

(d) RECOMMENDATIONS: On the basis of the results obtained to-date, it is apparent that the project should be continued in an effort to provide a better understanding of the history of this unique area. Some of the problems which need attention are listed below. In several cases these are re-statements of the recommendations accompanying my 1969 Annual Research Report.

1. Continue the efforts to determine the age of the early flows at Craters of the Moon. I believe we have a fairly valid date for the final activity - now we need to know when it began. From our experience in 1970 it is apparent that a new approach and new techniques will be required.

2. Continue the study of the xenoliths. These fragments, carried upward from the underlying basement rocks provide valuable information on the history of the Great Rift. A comparison of the xenoliths with outcrops of basement rocks in the adjacent areas would be useful.

3. Additional mapping and field studies of the "blue" lavas.

4. The apparent intermixture of "pahoehoe" and "aa" flows is not well understood. This feature, well displayed in the flow at the 1969 carbon site, is an example of one in question, but there are many others.

5. Detailed mapping of the individual lava flows from the Great Rift is necessary for a full understanding of the history of the area. The northern part of the Craters of the Moon area has been mapped (although some revision is needed) but in the southern part of the area only reconnaissance mapping has been done.

6. Further studies to clarify the history of the "monoliths" carried by some of the flows would provide useful information.

7. The conditions under which lava tubes develop is not well understood. There are many well developed lava tubes at Craters of the Moon and a critical study of these tubes would certainly contribute to our knowledge of these features.

8. Finally, it should be understood that the volcanic activity at Craters of the Moon is the final episode in a long volcanic history which included eruptions of rhyolitic material (including pumice) such as is now exposed at Big Southern Butte and elsewhere. Studies of this earlier activity is difficult because much of the material is now buried by later lavas. Nevertheless, this phase of volcanism is an important part of the history of the area and it should be investigated.

(e) FUTURE OF THE PROJECT: I recommend that the project be continued for a minimum of two more summers. I suggest that the plan followed in 1969 and 1970 be continued. In this plan certain objectives were selected for the summer's work and an effort made to complete those chosen. Thus, various units of the research would be completed as the project progressed, or in other words each summer is more or less an independent unit.



Appendix B.

HOLOCENE VOLCANISM IN CRATERS OF THE MOON NATIONAL MONUMENT AND ADJACENT AREAS, SOUTH-CENTRAL IDAHO

Bullard, Fred M., and Don L. Rylander, Department of
Geological Sciences, University of Texas at Austin,
Austin, Texas 78712

The lava fields and subordinate cinder and spatter cones in Craters of the Moon National Monument are the products of fissure-type eruptions from the Great Rift. The Great Rift extends from the Pioneer Mountains southeastward through the Craters of the Moon area and across the Snake River Pleistocene lava plain to the King's Bowl area, a distance of about 48 miles. The Great Rift is a series of en echelon fissures in a zone up to two miles in width. The individual fissures have only minor horizontal and vertical displacements.

The early eruptions from the Great Rift in the Craters of the Moon area produced largely pyroclastics, followed by numerous basaltic lava flows which spread in sheets and tongues up to 28 miles to the southwest of the Rift and 13 miles to the northeast, covering an area of about 600 square miles. The thickness varies from around 20 feet at the margin to approximately 200 feet near the Rift where many flows are superimposed. Several of the flows contain gneissic xenoliths. Lava tubes, varying from two feet or less up to tens of feet in diameter occur in many of the flows.

In the King's Bowl area, at the southeastern end of the Great Rift, the lava field covers only 1.1 square miles.

Charcoal rootlets of plants buried by the lava were obtained by tunneling under the flows. Samples for radiocarbon dates, collected in the north-central part of Sec.3, T.2 S., R.27 E., gave an age of 2080 $\pm$ 85 years B.P. This date does not represent the earliest or the latest activity, but is the date of a flow which is believed to have occurred late in the volcanic history of the area.

Classification (Please underline the single classification that most nearly encompasses the topic of your paper):

Coal	General	Geophysics	Oceanography	Sedimentology
Economic	Geochemistry	Hydrogeology	Paleontology	Stratigraphy
Engineering	Geology Education	Information Exchange	<u>Petrology</u>	Structure
Extraterrestrial	Geomorphology	Mineralogy	Pleistocene	Vertebrate
				Paleontology

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Speaker Don L. Rylander. Indicate authors who are not on mailing lists of GSA or of any of the Associated Societies. Don L. Rylander is not on GSA or Associated societies mailing lists.

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Appendix C

VOLCANIC HISTORY OF THE GREAT RIFT, CRATERS OF THE MOON NATIONAL MONUMENT, SOUTH-CENTRAL IDAHO

Bullard, Fred M., Department of Geological Sciences,
University of Texas at Austin, Austin, Texas 78712

The lava fields and cinder cones in Craters of the Moon National Monument are products of a fissure-type eruption from the Great Rift, a SE trending fracture zone traceable for 48 miles.

Trench Mortar Flat, an area roughly 0.5 x 1 mile, is in and along the east side of the Rift, 3.5 miles SE of the Visitor's Center. Here the west trace of the Great Rift is a trench up to 15 ft. deep and 10 to 20 ft. wide with the sides bordered by ramparts of spatter. Prior to the last eruption Trench Mortar Flat was dotted with Limber Pine trees. In the last eruption a flow of highly fluid, scoriaceous lava, from fountains along the Rift, covered Trench Mortar Flat. The base of trees near the Great Rift were buried by lava and the trunk and lower branches plastered with spatter, forming tree molds. The wood in the trunk and root system was carbonized. The average diameter of the 81 tree molds mapped was 14.4 inches with a maximum of 3 ft. Charcoal was obtained from 6 of the tree molds. The radiocarbon age for two of the samples gave an average of 2255 ± 60 years B.P. Charcoal from a tree mold in a pahoehoe flow near the base of The Watchman, 3 miles to the SE gave an age of 2140 ± 60 years B.P. A date of 2085 ± 85 years B.P. for a flow 13 miles to the SE was reported by Bullard and Rylander (GSA vol. 2, no. 4, p. 273, 1970). The close correlation of these dates indicates that the final eruptions of the Great Rift were widespread and of short duration. Charcoal was also obtained from roots beneath the lava at Crystal Ice Cave (on the Great Rift), 26 miles to the SE. This sample is being dated and the result will be incorporated in the conclusions.

Classification (Please underline the single classification that most nearly encompasses the topic of your paper):

Coal	General	Geophysics	Oceanography	Sedimentology
Economic	Geochemistry	Hydrogeology	Paleontology	Stratigraphy
Engineering	Geology Education	Information Exchange	Petrology	Structure
Extraterrestrial	Geomorphology	Mineralogy	Pleistocene	Vertebrate
				Paleontology

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