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RESOURCES MANAGEMENT PLAN
FOR
CRATERS OF THE MOON NATIONAL MONUMENT

I. OBJECTIVES AND GOALS

The essence of the Advisory Board's recommendations of March 4, 1963 is stated: "As a primary goal, we would recommend that the biotic associations within each park be maintained, or where necessary recreated, as nearly as possible in the condition that prevailed when the area was first visited by the white man. A national park should represent a vignette of primitive America."

Early white visitors to this area in the late 1800's were excited and awed by the stark volcanic landscape. It was an environment of weird beauty -- of suspended violence. Massive flows of fresh lava lay frozen in their churning advance. Dark orifices of caves beckoned exploration. Lava ribbons and spindle shaped "bombs" lay strewn about cinder cones from which they had been hurled. Wild animals scurried about on trails laced between sparse forests and ice-cold water holes. Silvery white forms of wind polished, dead pines dotted the black cinders.

It was this contrasting environment which President Calvin Coolidge proclaimed as a national monument in 1924 to preserve "a remarkable fissure eruption together with its associated volcanic cones, craters, rifts, lava flows, caves, natural bridges, and other phenomena...of unusual scientific

value and general interest." It is this environment which the Resources Management Program must now maintain. Except for the irreplaceable loss of wolves, bison and grizzly bears, there is no foreseeable reason why the scene prevailing in the late 1800's cannot be perpetuated.

That part of the Monument defined as Tutimaba Wilderness Area has been altered little, if any, by modern man. Its management shall provide future visitors an unusual opportunity to experience the same unspoiled "mood of wild America" which greeted visitors of nearly a century ago. In other parts of the area, large numbers of visitors may enjoy the same unimpaired resources through the use of facilities designed to minimize human alteration of the scene.

II. MANAGEMENT GUIDELINES

The management and use of Craters of the Moon shall be closely guided by National Park Service policies for natural areas, the Master Plan, the Long Range Wildlife and Range Management Plan, and the March 4, 1963, recommendations of the Advisory Board on Wildlife Management. These documents provide the standards; research and management experience will contribute the detailed working knowledge needed to meet such standards. Policies or guidelines of particular importance to this area follow:

A. Geological Resources: " The Service...shall...conserve the scenery and the natural and historic objects and the wild life therein and...provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (Secretary Lane's 1918 Directive).

It is important to recognize the deceptively fragile nature of the volcanic features in Craters of the Moon. As will be developed further in this Plan, careful management of human use and physical developments is necessary to prevent permanent damage to the area's primary resource.

B. Plant and Animal Resources: Craters of the Moon..."shall be managed so as to conserve and portray as a composite whole the indigenous fauna, flora, and scenic landscape. Management will minimize, give direction to, or control those changes in the native environment and scenic landscape resulting from human influences or natural processes of ecological succession. Missing native life forms may be reestablished, where

practicable, at levels determined through historical and ecological research of plant-animal relationships..." (NPS Policies).

1. Control of Excess Populations: Overpopulation of ungulates, with resultant deterioration of preferred habitat throughout the Monument, is a recognized possibility. Fortunately any needed reduction can likely be done by public hunting outside the Monument boundaries. Direct control within the boundary will be limited to very local reduction within chronic range damage "spots", and then only if other means fail.

Natural phenomena { It is conceivable also that other types of animals or plants may tend to disrupt the original scene due to unusual abundance. Periodic research will identify such problems and devise control measures which will cause minimum disturbance to other elements of the environment.

2. Plant Pest Control: The "composite whole" discussed in the Service policy on Plant and Animal Resources includes a variety of organisms often deemed pests when they destroy trees and other plants. Such organisms have coexisted for centuries with the vegetative cover in Craters of the Moon. The scene confronting the first white visitors was one produced by this "composite whole". Interspersed with living stands of limber pine were burned-over areas in varying stages of recovery. Silvery trees which had died decades before displayed the fascinating branch development resulting from dwarfmistletoe growth. The shrub-grass communities on older cinder cones were the products of

fire, insects, plant diseases, ungulate and rodent utilization, and other natural forces.

Pending research efforts, it appears that man's interference will not often be required to maintain the original scene. Yet, plant pest control must be practiced in Craters of the Moon if and when comprehensive research determines that desired conditions are being seriously threatened. Scientific examination should periodically determine the status of the biotic complex to guard against damaging influences. Such influences might be exotic pests, or unnatural populations of indigenous organisms resulting from human activities within and outside the Monument.

Use of chemicals and insecticides should be reviewed in light of the Advisory Board's observation that "the mass application of insecticides in the control of forest insects...can have unanticipated effects on the biotic community... It would seem wise to curtail this activity, at least until research and small scale testing have been conducted." (See III C for list of plant pests.)

3. Fire Control: As discussed in the previous section, the original scene was not a product of modern control efforts. Natural fires are essential to the maintenance of ecological communities of mixed successional stages. Unless lightning caused fires periodically sweep over portions of the vegetative cover, original conditions will be altered. The value of the Monument as a natural ecological research

unit will be simultaneously negated.

Lest the reader be alarmed, it should be pointed out that vegetation is sparse at Craters of the Moon. Approximately two thirds of the total area is barren lava. Islands of vegetation sit at right angles to prevailing winds and are well protected by natural fire-breaks. Relatively few fires occur. The 22 year average is one fire every three years. It is not uncommon to find isolated limber pine trees which have been ignited by lightning, then ceased burning for lack of adjacent combustible material.

Man-caused fires, or any fires which threaten major portions of the landscape, developed facilities, or neighboring land outside the Monument, shall be extinguished. Suppression can and shall be accomplished without mechanical disturbance of the terrain. Natural caused fires of moderate size which will burn themselves out against lava barriers shall be kept under surveillance, but extinguished only when compelling reasons demand. Especially in the Tutimaba Wilderness, there would seldom be reason to control fires unless they were unusually prolonged or extensive. *(may be controlled fire is needed?)*

Public opinion is important in such a program. Adequate public information efforts shall precede any permissive or prescribed burning. The matter should be treated as a unique opportunity to bring into public focus the objectives of the National Park System.

4. Restoration of Extirpated Species: As they pointed out by the Advisory Board, "Native species of wild animals should be present in maximum variety and reasonable abundance." Bighorn sheep, which became extinct at Craters of the Moon in the 1920's, should be re-established. Research will determine the best methods of doing so. Other extirpated species of animals and plants which can be practicably managed should also be restored. Efforts will be continued in cooperation with the State Fish and Game Department to encourage seasonal return of Wapiti and Pronghorn to the Monument.

5. Control of Exotic Species: Research will appraise the existence of exotic plants and animals, and possible methods of eliminating them. Chukar and Hungarian partridges are known exotic birds. Certain exotic plants are recognized; some are now controlled in certain locations.

C. Resource Use: In accord with Service policy management shall "Provide for all appropriate use and enjoyment by the people, that can be accommodated without impairment of the natural values. Park management shall recognize and respect wilderness as a whole environment of living things whose use and enjoyment depend on their continuing inter-relationship free of man's spoilation."

1. Recreational Use: Service policy further provides that, "In natural areas, outdoor recreation activities such as hiking, mountain climbing, bicycling, horseback riding, sightseeing, water-oriented activities, winter sports, nature observation, photography, camping,

picnicking, and the like, that can be accommodated without material alteration or disturbance of environmental characteristics are to be encouraged, and provision shall be made to facilitate public participation in them."

The present visitor use at Craters of the Moon, and that proposed in the Master Plan, is in line with the above policies. Bicycling will be restricted to vehicle roads because it would be inconsistent with the wilderness mood along the trails. Winter sports will be limited to cross country skiing, tobogganing and those activities not requiring mechanized equipment. Use of over-the-snow equipment shall be restricted to developed roadways used by visitor vehicles in the snow-free season. There is neither a proper location nor justification for development of "mass recreation facilities such as golf courses, ski lifts...and other extraneous developments which...contradict the management goal." (Advisory Board)

A day-use pattern will be stressed in the Tutimaba Wilderness, where most features can be visited in a one-day outing. Where overnight camping is desired, visitors will be encouraged to practice modern techniques. Lightweight, self-contained camping gear will generally eliminate the need for fire-wood cutting or permanent facilities in this area of mild summer climate. Refuse shall be carried out by the individual. Use of dwindling waterholes for camp water shall be prohibited.

2. Research: "The public use, protection, development and interpretation of the natural and cultural resources of (Craters of the

Moon) shall be predicated on documented data obtained through appropriate investigation and research. Moreover, the use of the resources...for study or research purposes by recognized educational and scientific institutions and accredited individuals shall be encouraged. Pursuant to the achievement of these policies, the collection of reasonable numbers of biological and geological specimens and historic artifacts and objects may be permitted." (Service Policy)

The Advisory Board similarly states, "A greatly expanded research program, oriented to management needs, must be developed... Both research and the application of management methods should be in the hands of skilled park personnel."

As this Management Plan brings out, nearly every management function at Craters of the Moon will be directly or indirectly keyed to qualified research.

It should be mentioned here that Craters of the Moon has passed the point of diminishing returns regarding collection of geological specimens. There is little reason routine samples of lava and cinders need be collected within the area. They are abundantly available outside the Monument. Tree molds and volcanic bombs, on the other hand, are limited to the Monument proper and are particularly sensitive to public collection. Specimens of these have been gathered so much in the past that those remaining are now invaluable.

Only genuine scientific needs warrant permission to collect. Documentation should include full evidence that the specimens will be used to provide new or important knowledge in the field of volcanology. The mere request by a college or university for a "representative collection" is no longer adequate justification. Photographs can certainly suffice for classroom use. With proper explanation, our position is readily understood by teachers of geology.

3. Concessions and Other Business Operations: Service Policy states: "Where adequate public accommodations, facilities and services exist, or where it is feasible for them to be developed by private enterprise outside a natural area, such shall not be provided within the area." Craters of the Moon is a twenty minute drive on all-weather highway from a community with complete traveler facilities. Within two miles of the Headquarters-development area, just outside the boundary, are good business locations, should the need for such arise. There appears to be no need for concessions within the Monument.

D. Physical Developments: "Only those physical facilities needed for management and public use shall be provided in (Craters of the Moon) and only at sites designated on the approved Master Plan." (Service Policy)

In general, any future residences, utility buildings, campgrounds and other supporting facilities will be built in the northwest corner of the Monument. This location is outside the primary resource area.

The terrain lying generally southeast of Highway 20-26-93A shall be a

day-use area. Because of the deceptively fragile nature of the geologic formations, developments along the loop road system shall be carefully designed to minimize human damage.

III. INVENTORY OF EXISTING RESOURCES

A. Geologic Resources: See appendices A & B, Photo Section, Section VI and page 2 of the Master Plan.)

The Monument was established to preserve for public benefit an unusual array of volcanic resources. Nearly every known phenomenon of basaltic volcanism may be observed within the boundary. The basic feature is the Great Rift -- a linear zone of seismic fissures which has repeatedly and rather recently produced a chain of volcanic features along its length. The most interesting one-third of the 45-mile Rift lies within the Monument.

Oriented along the fissures are 35 major cinder cones, several series of spatter cones and over fifty individual lava flows which radiate outward for many miles. The oldest flows appear to be approximately 1,000,000 years old. The most recent activity occurred about 2,000 years ago.

Lava appears in both the rough, clinkery aa type and smooth pahoehoe with its beautifully frozen flow patterns. Large cinder cones, up to 800 feet in height, are the source of spindle-shaped, ribbon, and cow-dung "bombs" that lie strewn about the orifices. Some of the spatter cones contain deep crystal-walled pits. Large fissures reveal the orientation of the Rift zone; some are coated with spatter as evidence of the last activity. Numerous tree molds preserve in detail the shapes of trees

which were flooded with lava. In the more massive pahoehoe flows, lava tubes occur. Some of these are reservoirs of ice deposits which persist throughout the summer. Lava stalactites, lateral tube systems, rippling flow patterns along the floors of the tubes, and evidence of re-melting by superheated gases lend interest to the "caves".

The most recent lava flows appear very new. Seemingly unweathered surfaces and bright iridescent colors led early visitors to the logical but incorrect assumption that the area had been active within the previous century.

Natural waterholes occur throughout the Monument. Depressions in the terrain reveal the melting surfaces of ice layers which collect deep within the lava during winter. The bubbly structure of lava rock acts as good insulation. Thus a small supply of ice-cold water persists all summer. From time to time some of the waterholes dry up, then reappear in later years. Since 1920, at least, many of the waterholes seem to be drying up.

Another feature of interest is the large number of angular crater wall fragments which dot the otherwise smooth expanse of lava flows. These red pumice monoliths were swept from the cinder cone walls by lava which welled up inside the cones and broke through the sides. Some fragments have been rafted as far as four miles.

89226 Skelton
If fire 4900214
Care removed this
area would become
bunchgrass
prairie

B. Plant Communities: (See Appendices C, F, & Photo Section) Craters of the Moon is located on the northern edge of the Snake River Plain. As does much of southern Idaho and northern Nevada, it lies within the Artemesian Biotic Province, an area typified by low precipitation and a wide range of temperatures, both seasonal and daily. The climax plant community is sagebrush-grass. Local exceptions occur where streams or wind-deposited snows provide moisture for thin strands of coniferous and broadleafed trees. Certain soil conditions permit isolated examples of pure grassland communities.

Mature soil accumulations in the Carey and Round Knoll Kipukas, the Little Cottonwood area, and in the southeast section of the Monument permit climax vegetation. Edaphic variations generally determine differential abundance of the dominant species. Characteristic shrubs are big sagebrush, three-tip sagebrush, alkali sagebrush, antelope bitterbrush, rubber rabbitbrush, and Douglas rabbitbrush. Characteristic grasses are Idaho fescue, bluebunch wheatgrass, Sandberg bluegrass, western needlegrass and giant wild rye.

Most of the Monument is composed of recent lava flows and young cinder cones, where subclimax plant communities prevail. Insufficient time has elapsed since the last eruptions to produce a soil mantle capable of supporting the climax community. Vegetation on young lava flows is much different than that of the cinder cones:

1. Young lava flows: Soil filled cracks, crevices and depressions provide sporadic habitat for such shrubs as Lewis mockorange,

tansybush and rockspirea. Limber pine also grows sparsely in the flows. Characteristic forbs are scabland penstemon and gland cinquefoil. As the flows increase in age and soil accumulation, the sage-grass community will crowd out these pioneer species, including the limber pine. Change is imperceptibly slow; some flows over 2,000 years old still appear almost completely barren.

2. Cinder cones: The pioneer community on young cones is a widespread but sparse covering of herbs such as dwarf monkeyflower, buckwheat, phacelia and Lewis bitterroot. In sequence, this community is replaced on northfacing slopes by limber pine. Antelope bitterbrush advances on the south and west slopes, to be replaced in turn by the climax sage-grass community. Limber pine will also eventually give way to sage-grass on the north slopes except where snow conditions favor the trees.

Advanced ecological research is needed to sophisticate our knowledge of plant succession, particularly as influenced by edaphic, micro-climatic, and fire conditions.

C. Plant Pests: Many organisms depend upon plants for food, shelter and other life requirements. Of these, only dwarfmistletoe has been considered sufficiently damaging to warrant control measures. Active eradication of infested trees, and infested limbs of otherwise healthy trees, was carried out from 1962 through 1965 in the general scenic area of the loop road system. (See appendix D) The program is not yet completed. (Grand Canyon Scenic)

Other organisms which occur in the area and which could possibly warrant control at some future date are:

White-fir sawfly
Douglas fir tussock moth
Tent caterpillar
Mourning cloak butterfly
Pine engraver beetle
Red turpentine beetle
Twig beetle (Carphorborus sp.)

D. Wildlife Distribution: Wildlife resources in the area are surprisingly rich and varied. (See appendices G, H & I)

1. Resident species: Rodents common to all vegetated portions of the area are yellowbelly marmot, chipmunks, Columbian ground squirrel, mantled squirrel, deer mouse, and voles. Porcupines and red squirrels are found in the forested areas. Mountain cottontails, whitetail and blacktail jackrabbits occur in cyclic numbers. The rare pigmy rabbit may occur in the Monument. In fissured lava flows near sage-grass communities a few Pikas can be found.

Coyotes, red foxes, bobcats, longtail weasels, badgers and spotted skunks are resident ^{Carnivores} mammal predators. Black bears occasionally enter the Little Cottonwood drainage, but are usually soon shot by sheepmen outside the boundary. Golden eagles, great horned owls, redbill and roughleg hawks, ravens and magpies can also be seen all times of the

year. Resident non-predatory birds include sagegrouse, blue grouse, Clark's nutcracker, and mountain chickadee.

Characteristic reptiles include horned lizards, Great Basin rattlesnakes, rubber boas, gopher snakes and western skinks. Most of these are found in the older sage-grass areas.

2. Migratory species: In the summer the lava-flow water holes are a flurry of mourning doves, bluebirds and violet-green swallows. The stream-fed valleys of the Little Cottonwood area host warblers, finches, towhees, woodpeckers and wrens. Chuckar and Hungarian partridges nest in the rye-grass flats. Broadtailed hummingbirds can be seen during peak flowering of the shrub species. In late fall, flocks of pinyon jays pass through the foothills.

Perhaps the most exciting wildlife observation to visitors is the sight of mule deer. They can be seen almost any morning or evening along the loop road during the summer season. Close observations during 1964 and 1965 indicate a herd of approximately 300 spend the summer and fall months within the Monument. About half are distributed along the Rift zone; the remainder can be found northwest of Highway 20, 26, 93A in the Little Cottonwood area.

The deer population has increased considerably in the past few decades. This is linked with a general increase in mule deer throughout the intermountain west. Suppression of grass species on open range by domestic livestock has released vigorous growth of shrubs. Thus the

cattle range becomes poorer while the deer range improves. The deer may be expected to continue this ^{to} increase in the next few years unless the hunting harvest outside the Monument is ^{increased} enlarged.

The mule deer follow a ^(established) predictable migration pattern. (See Master Plan page 20) They arrive as the snow melts in April and May. The deer which summer in the lavas enter the area in the northwest corner and disperse throughout the Rift zone. Those which summer in the westerly foothills are scattered both in and out of the Monument in the Pioneer Range. As summer progresses and domestic stock are brought into the ^{OG-PA 40} ^{Monument} hills, more and more foothill deer are driven into the Little Cottonwood drainage. This build-up continues into the October-November rutting season. When deep snows arrive between early November and January, practically the entire deer population of the Rift zone and Little Cottonwood leaves the area. The exodus is brief. A single trail may be used by more than a hundred animals in one or two nights. Their winter range appears to be in the Antelope Creek-Newman Canyon area near Arco and Moore.

In mild winters a few deer sometimes spend the winter in the southeast part of the Monument. It is presently not known if these are the same deer which normally winter northwest of the area. It is possible they are part of a group oriented southeast of the Monument which overlap summer ranges with the Arco area deer.

Craters of the Moon lies midway between summer and winter ranges of a sizeable ^{pronghorn} antelope herd. In May and June antelope bands are

seen almost daily, passing southwesterly along the Oregon Trail Cutoff. Their route parallels Highway 20-26-93A. Visitors see them frequently. The animals spend the summer in the Fish Creek area. From September to late November the migration is reversed. A single band of over 100 animals has been seen traveling toward Arco during the falls of 1964 and 1965. The current total of all ^{herds} bands is approximately 200 to 250 animals.

A small herd of wapiti ranges less than ten miles northwest of the Monument. Occasionally a few of them enter the area during winter. It is debatable if the Little Cottonwood area is large enough to attract them on a summer range basis. They are hunted each fall and may never extend beyond their present home range.

E. Water Rights and Water Management: Little Cottonwood Creek and the unnamed southwest branch of said stream comprise the sole water supply for the Monument. An extensive pipe system transports the water to the point of use at area headquarters. (See page 15 of the Master Plan)

Existing State water rights are:

1. License and Certificate of Water Right No. 16,711, with priority of July 21, 1927 for 0.055 cubic feet per second. License issued May 9, 1939.
2. Supplementary License and Certificate of Water Right Number 28,964, with priority of August 25, 1960, for 0.20 cubic feet per second. License issued November 19, 1965.

The "waterholes" of the lava fields are nothing more than snow melt perched on layers of ice. They have been treated in this Plan as geologic features.

F. Historical Resources: (See Section IV for historical references)

1. Archeological remains: Research is needed to make order of the variety of archeological evidence within the Monument. It is unlikely that any information will be obtained which will add significantly to the general knowledge of Idaho Indians. This area is a small element of the region formerly occupied by them. Yet knowledge of their specific activities while in the unusual environment of Craters of the Moon is very interesting to visitors and a worthwhile area of secondary interpretation.

We know that the Shoshoni people traveled across the Rift zone as they went between the Ft. Hall area and the valleys of the Wood River. They called it Tutimaba (Black Rock Overpass) because it is about 1,000 feet higher than valleys on either side.

They also traveled along the Rift zone, on a northwest-southeast line. Cinder fields dotting the fissure made far easier traveling than adjacent rough lava fields. Deep snow drifts in cones and vents provided a source of water throughout most of the summer months. Permanent waterholes were a source of game as well as water. Hunting blinds in Little Prairie are strategically located downwind from waterholes, to take advantage of game coming for a drink.

Better grades of basalt were quarried for implements at several sites surrounding Big Cinder Butte. Most artifacts are made of material foreign to the area, however. Pottery has been found in several places.

2. Early Whiteman History: In the early 1800's a major trail skirted the Monument Area on the northwest edge of the lava flows. This eventually became a wagon road -- the Goodale Cutoff of the Oregon Trail. Beginning in 1852, wagon trains, stagecoaches, and cattle drives used this route extensively in traveling between the eastern states and Oregon-Washington. Thousands of cattle were trailed on the Goodale Cutoff in the 1880's as herds averaging 2,000 head in size were taken from Oregon to Wyoming and Montana.

Though the "Craters" were often mentioned in early journals, and fanciful tales repeated about the wonders therein, it was not until 1879 that whitemen penetrated the interior of the Great Rift. J.W. Powell and Arthur Ferris traveled the Rift in search of stock watering locations. Local reports finally resulted in a Geological Survey visit in 1901. Formal Geologic studies were begun by Dr. Harold Stearns in 1921.

After 1900 the area was used for stock grazing purposes by local ranchers. Wagon roads were built on the edges of cinder cones, extending into Little Prairie. In about 1920, Era Martin constructed a concrete watering trough at Little Prairie waterhole. This was abandoned,

apparently, as it only watered seventy head of stock for eleven days before the waterhole went dry.

Interest grew and pioneer sightseeing parties visited the area each year. By 1920 various individuals were promulgating the National Monument proposal. This interest was led by R. W. Limbert of Boise, Idaho, who lectured and wrote about the area. An article by him in the March, 1924 issue of National Geographic Magazine climaxed his efforts. Two months later, the Monument was established.

G. Disturbed Areas: Only the Little Cottonwood watershed can be considered disturbed from its original condition. An early effort at ranching was made in the meadow prior to 1915. In the 1920's a number of mines were very active. One claim is still in private ownership at the time of this writing. Ecological as well as physical damage has occurred in this area. Exotic weeds are abundant in the stream valleys. A variety of roads and diggings scar the landscape somewhat.

IV. INVENTORY OF ORIGINAL CONDITIONS

There is little need to discuss here original geologic conditions. With the exception of minor human damage and removal of certain features, the volcanic phenomena are essentially unchanged. Biological resources are much more subject to alteration. The sketches which follow have been assembled from Monument files and from the references given below. Old photographs have been particularly helpful in appraising original vegetative conditions. The near-pristine Carey Kipuka provides an unusual reference to original conditions of the sagebrush-grass climax community.

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A. Original Vegetative Cover: Forthcoming research will naturally refine our knowledge of both past and present ecological relationships. Until then, current knowledge indicates that vegetative communities of Craters of the Moon National Monument have changed very little and, in fact, are rather resistant to cumulative alteration by natural and unnatural forces prevailing today.

Photographs and texts of early publications show that vegetative conditions have not been altered materially since whitemen first visited

the area. In the edaphic subclimax communities of the more recent cinder cones and lava flows, the tree cover may have been slightly thinner than today. Otherwise old photos of both these areas and climax communities might easily have been taken in 1965.

Present conditions could easily support activities of the past: Cattle herds up to 3,000 in number were trailed through the edge of the lavas repeatedly in the 1800's. The drovers reported fair grazing on the mixed sagebrush-grass communities. Era Martin found favorable stock feed all along the Great Rift in the early 1900's and possibly before. Early travelers cut firewood within patches of pine trees which existed on the north faces of nearly all cinder cones despite recurring range fires. Many of our living trees are several centuries old.

As Hugie has pointed out from studies in the protected Carey Kipuka, differential composition of the climax sagebrush-grass community is the result of soil differences. It follows that selective grazing by cattle or bighorns, which prefer grass, will tend to create an increase of the less palatable shrubs. At the other extreme, utilization by deer or antelope will tend to reduce the shrub cover and increase the percentage of grasses within the plant community. Fire, drought and other climatic variables will produce similar temporary changes in species composition. These fluctuations are apparently not cumulative and do not permanently alter the plant community. Given respite from such influences, the climax community can be expected to restore itself.

A visit to the Carey Kipuka, followed by examination of climax communities in other portions of the Monument, will further substantiate the premise that major changes have not occurred. Minor compositional differences have perhaps resulted from introduction of certain exotic plants by domestic stock, or from comparatively recent burnings, but the basic pattern persists. (The Carey Kipuka itself was once grazed but it has been accepted as "near-pristine" by scientists.)

The same continuity appears to hold true for pioneer communities on the youngest flows. A list of lava flow plants compiled forty years ago is accurate today.

The effect of range fires at Craters of the Moon is an important consideration, for it is well known that both whitemen and Indians were inclined to burn sagebrush to improve grazing conditions. Era Martin started the fire that left charred trees later attributed by Limbert to recent volcanism. Dr. Harold Stearns states in recent correspondence, "in 1921, evidence of fires was common, possibly set by lightning or sheepmen or both. The sheepmen did not want sagebrush as it kills out the grass. Limber pine grew sparsely. Burned logs and stumps of some were noted and probably are still around as they rot very slowly, especially when charred."

The Monument staff was surprised to find in the files that a 1945 man-caused range fire swept through the northwest corner of the Monument, burning over all of Section 22 and most of Sections 21, 23, 27 and 34. Today, the evidence is scarcely visible. Vegetative analysis might

show a temporary deficiency of some plants; otherwise the area has essentially recovered in twenty years. Moreover, the islands of trees within and adjacent to this fire were unburned, perhaps protected by convection patterns characteristic of sharp-facing leeward slopes.

A 1957, 50-acre, man-caused fire just north of area headquarters gives further insight into the recovery rate of the climax community. Eight years later we find mixed native grasses still dominant, but rapidly being joined by antelope bitterbrush and rubber rabbitbrush, which now comprise about 10% of the vegetation.

Despite a moderate number of lightning fires, and what may have been a large number of man-caused fires prior to establishment of the Monument, the tree cover has survived well. Of the seventeen cinder cones having mature limber pine groves on their north slopes, only one seems to have suffered seriously from fire. A lightning fire in 1949 destroyed a 15-acre patch of limber pine on the north slope of Coyote Butte. Tree cover on the lava flows is generally too sparse to sustain a spreading fire. Only where shrub growth is sufficiently dense on the older flows and cones can fires endanger large acreages of Monument vegetation.

Grazing apparently continued through the 1930's. Files show Martin was given a grazing permit "for the Monument" in the year 1930. No record is available to show when grazing was terminated, but it was surely stopped by the late 1940's. Native grazing animals -- bighorns, elk and bison -- were gone before the Monument was established, thus in some

respects domestic livestock use replaced these animals in terms of the range utilization pattern.

From the evidence available, we can tentatively visualize vegetative conditions which obtained when the first whitemen entered the Rift zone in 1879. Most of the area -- the zones of recent volcanism -- appeared the same as today. The evidence of fire was common on the older flows and cones, where climax sagebrush-grass communities in various stages of recovery tended to regain climax compositions within two or three decades. Small patches of burned limber pine trees were also slightly more in evidence than today. Grazing by bighorns balanced in some degree the almost strict browsing habits of deer and antelope. Southwesterly ridges of the cinder cones probably suffered from over-utilization by all three native ungulates in wintertime. Disturbed areas were not temporarily invaded by the introduced Bromus tectorum, cheat grass, as some are today. Mistletoe clung to the limber pines then as now.

B. Original Wildlife: Field notes by Stearns (1926) indicate that small animals and birdlife occurred much the same as now, except for sage-grouse, which were strikingly abundant then. Chuckers and grey partridges were not introduced until later.

Era Martin had killed a number of grizzly and black bears in the Monument between 1884 and 1920. Stearns noted denning of bears in the lavas and extensive bear grazing of the wild parsley. Era Martin was attempting

to live trap a bear near Inferno cone in 1921. Since that time, black bears are generally intercepted and killed by sheepmen before they can enter the area from the Pioneer Mountains. Otherwise they would undoubtedly occur in the Monument today. Grizzlies are now extinct in this part of Idaho.

Era Martin claimed that antelope, deer and bighorns were abundant in the "early days" -- presumably the 1880's and 1890's. Stearns noted many bleached skulls of antelope, deer and bighorns in the southeast part of the Monument where they previously wintered in numbers. By 1921 the deer and sheep were essentially gone; antelope still passed through the area, but apparently no longer used it as winter range. Goodheart mentioned seeing large herds of elk in the foothills near the northwest boundary in the 1860's, but no other reference has been found of elk being in or near the area. Horns and bones of bison found in the lavas as recently as 1965 indicate these animals made some use of the area.

V. ANALYSIS OF REQUIRED MANAGEMENT

A. Fragile Geologic Features: Lava is deceptively weak. Filled with gas bubbles, it can more accurately be called rock foam. From an airplane one can easily spot areas of human use by the red-brown coloring of the broken surface, as contrasted with the oxidized gray of the undisturbed surroundings. Even casual walks into the roadless areas create minor but cumulative damage. ✓

Obviously, only another volcanic eruption could repair the steady disintegration caused by weathering and human use. Because they are not regenerative, like a biological resource, the volcanic features must be managed more carefully than an alpine garden if they are to retain their unique character. ✓

Waterholes of the lava landscape are subject to pollution and disturbance. ✓
Dr. Harold Stearns writes, "my impression is that the waterholes have ✓
been disappearing, possibly from removal of the water by visitors."
(Waterhole management is discussed in Section V paragraph E because they
are primarily involved with wilderness use)

Management of the geologic resource is the Service's most important responsibility at Craters of the Moon. The keynote is protection. ✓

Several aspects apply:

1. Physical development: Well planned roads, trails and interpretive facilities are an important deterrent to improper use. A mistake of the past is the dead-end trail. Visitors with an appetite for stimulation

are naturally disinclined to return via the same route. Damage radiates from the ends of such trails. In contrast, a loop trail brings visitors back to the point of origin without giving them cause to invent their own return route or means of entertainment.

The spatter cone area at Big Craters is a special problem. The cones are unusually inviting to exploration and at the same time unusually subject to damage. A lacework of trails have been worn into their sides. Trail obliteration has not been successful. A series of paved, fenced trails and unobtrusive barriers appears to be the only solution. Studies are now underway to design protective facilities which will not limit use and enjoyment.

The present campground is located within an important lava flow. The side effects of human activities which spread from a campground are not terribly serious in an average campground location. But here they cumulatively damage a primary resource. The obvious solution is to relocate the campground in an area of less importance. A day-use pattern should be maintained southeast of the headquarters area.

2. Visitor Education: This is a fertile field. Orientation at the visitor center has been successful in placing visitors in the proper frame of mind prior to going out into the area. A few well designed signs can transmit maximum information and tactful regulation. Proper explanation of waterholes, their importance to wildlife and sensitivity to disturbance can reduce damage to these interesting features.

Both rangers and naturalists have made a religious habit of picking up litter in the presence of visitors while on patrol or interpretive hikes. This has elicited excellent response. A roving uniformed man at the spatter cones and cave area is highly effective in preventing specimen collection and other improper use. Much more can be done in this regard.

3. Enforcement: Outright vandalism is another concern. Stalactites are steadily broken off in the lava tubes. Tree molds fracture easily and small pieces are treasured by rock-collectors. Bright red pumice is chopped from crater walls and taken home for rock gardens. Spatter cone vents are continually filled with rock fragments because of an irresistible human compulsion to hear a rock strike bottom.

Persons come from all parts of the United States to collect lava "bombs" at Craters of the Moon. This is done despite clear knowledge of regulations. The common term in local universities is a "bomb raid on the Craters". Laws of supply and demand have produced diminishing success in their endeavors because bombs are now scarce near the road system. Yet it will continue to be a problem and the Monument staff must always be alert for such individuals. Efforts must be made to address each visiting group of geologists and students -- appealing to their sense of responsibility.

B. Landscape Protection and Restoration: It is almost impossible to obliterate old road scars in open cinder fields. Equipment or handwork

can be employed to restore contours of the terrain. But the following year the work is betrayed by a profusion of plants which crop up in a nearly barren cinder field. Invisible tiremarks and footprints are vividly painted in wildflowers due to plant preference of disturbed and compressed cinders. In answer to this, cinders have been gently raked into old road ruts, with no walking or other compression registered. This is successful if the cinders are taken from the same area, otherwise the road location is revealed by inevitably contrasting cinder colors. As a last resort, a light covering of cinders may be scoop-shoveled from the sides of the road over the uncompressed fill material. This is effective but costly, as it involves much final dressing by hand-labor.

Obliteration of old stump scars left by early pioneers has been accomplished by blasting off the tops to simulate a wind-broken tree. This is being done close to the road system. Once completed it should not require repetition.

County and State road crews hired for area road maintenance are not always oriented to Service objectives. Strict vigilance by rangers is necessary to keep them from turning road graders around in the cinder gardens or parking heavy equipment off of the pavement. Asphalt curbing planned for much of the forthcoming loop road reconstruction will aid in keeping vehicles off of the easily disturbed cinder fields.

Service employees themselves are sometimes led astray from established objectives by other pressing concerns. Some 6,000 trees were inadvertently felled within the loop drive area in a mistletoe control effort

15 22 15 1/2 lb
part of this scene?

before it was realized that the trees could simply be poisoned in place. Dead trees are part of the original scene. Saw cut stumps are not. Fortunately a careful clean-up program has minimized cutting effects visible from the road system. ✓

The "vignette of Primitive America" can and should meet the motorist's eye from road shoulder to infinity. Avoidance of unnatural effects in the intimate roadside scene must remain a special chore at Craters of the Moon. Road reconstruction efforts will always have to accept the fact that abandoned road alignments in this volcanic landscape are nearly impossible to erase.

Because of more normal soil conditions, landscape restoration in the Little Cottonwood area can be accomplished by more conventional means. If and when public use is brought into this area, machine landscaping and reseeding should meet with success. Little effort has been made in this regard and the matter will retain low priority at least until the one remaining mineral claim is acquired.

As has been mentioned under guidelines for fire control, use of bulldozers or other heavy equipment for fire-breaks must be avoided, as the resultant scar lasts much longer than the worst possible effects of any fire. For the same reason, Service use of vehicles off the established roads must not be permitted.

The use of cinders for roadbeds and other maintenance work has been the established practice since the Monument was created. Several

thousand yards of cinders have been taken from the east slope of Inferno Cone and the cinder ridge east of headquarters. The two pits have made sizeable marks on the landscape. This cannot go on indefinitely without marring the original scene. These pits should be closed and landscaped by 1970. Ultimate construction of the loop extension around Big Cinder Butte, as proposed in the Master Plan, may require the use of a new borrow area in that vicinity for practical reasons. Otherwise, future fill material should be obtained outside the loop drive area, and preferably outside the Monument. Adequate cinder pits occur just outside the boundary on BLM lands. Haul distance would not be over four miles from headquarters. 20

C. Management of Vegetation: It is not only the trained observer who is fascinated by the unique vegetation of Craters of the Moon. When the dwarf monkey flowers form purple lawns upon the cinderfields, or when the bitterbrush crowds the landscape with blooms of yellow, visitors are noticeably impressed. The story of plant succession is unusually revealing in the mixed-aged segments of the terrain. Also, a significant wildlife resource depends upon maintenance of original plant conditions. Careful vegetative management is thus an important Service obligation. ✓

1. Fire Control: (See Appendix E) As the Advisory Board has indicated, fire must be respected not only as a thing of evil, but also as a helpful means of natural management. Guidelines given in Section IIB shall be followed. Original conditions must always be kept in mind.

✓

This means that permissive burning will be applied in certain circumstances -- that some fires will be allowed to run their natural courses. It would be naive to overlook the fact that a half-century of fire-prevention publicity has trained the American public to equate fire with harmful destruction. Controlled burning by the Forest Service, State Game and Fish Departments and other agencies has been done only after careful public relations groundwork has been accomplished. Permissive burning at Craters of the Moon must be preceded by the same efforts.

It will be a task of education and persuasion. Properly presented, it can be an unparalleled opportunity to carry across to the public the very special mission of the National Park Service. If the program is approached too quickly or without respect to public understanding, local and national resentment might easily occur.

Yet it is understandable that fire was a natural part of the original scene. The mixed plant communities which follow a burning are beneficial to mammals and other life. From another point of view, mixed pattern of burned-over areas in varying stages of recovery is a surprisingly good system of fire-breaks. Nothing is a greater fire hazard than a large, continuous area of dense vegetation which skilled fire suppression crews often produce.

As a tool, fire can be used to manipulate the vegetative cover toward desired ends. For example bitterbrush appears to be more abundant in the second and third decade following a burn. Accordingly research may

✓

establish burning as a means of increasing deer forage. Similarly, by more frequent burnings the area can be kept in a nearly pure grass stage if reduction of deer forage is desired. Evidence also exists that fires may hinder large buildups of certain insects and plant diseases.

The guidelines for fire control and permissive burning must be followed with judgement. Weather conditions and other variable factors make it difficult to define on a map the exact zones wherein natural fires will be permitted to burn. Appendix E is a guide to fire control zones, yet only on-the-spot judgement can determine when a moderate sized fire may become one which "threatens major portions of the landscape or neighboring lands." Until the public has thoroughly accepted permissive burning as a sound practice it seems wise to suppress any doubtful fires.

Man-caused fires have repeatedly swept over the northwest corner of the Monument. All fires in this area will threaten neighboring lands and accordingly must be suppressed if possible. Because of repeated man-caused burnings here, there is little danger of original conditions being upset by lack of fires.

The mandatory control zones in the southeast section have been free of unnatural fires, but are the only other areas where Monument vegetation is continuous with neighboring lands.

The techniques of fire suppression must depend upon methods which do not leave bulldozer swaths and truck tracks on the landscape. Backfire and

flanking attack with handtools, coupled with aerial deliveries of fire retardants will normally be adequate. Future new developments in fire suppression methods will undoubtedly be helpful in accomplishing the task without scarring the landscape. Fire suppression capabilities must always be maintained by the Monument staff.

Prescribed burning does not appear necessary at this time. Research may establish a need, however. If so it shall be done with proper advance planning to maintain full control.

2. Plant Pest Control: Sections IIB and IIIC present guidelines for control of plant pests and an inventory of those organisms which might possibly require such control. Not enough is known at present to make predictions. Exotic pests may be expected to arrive in this part of Idaho from time to time. Annual inspections by qualified technicians must be continued. Research programs which might shed additional light on the situation will be encouraged.

The dwarfmistletoe control program begun in 1962 has been a subject of concern. It can be argued that within the experimental control zone up to 90% of the limber pine forest has been destroyed by the eradication program. There is no positive proof that the remaining 10% will not also be infected. Certainly the control program has upset original conditions more than would many years of misteltoe infestation. It is clear that mistletoe has infected the limber pines at Craters of the Moon at least for several centuries past. - Natural }

On the positive side however there was reasonable biological evidence that mistletoe could cause serious mortality of the forest if left unchecked. The control zone was established as an experiment. Only a small portion of the Monument's pine forests was included. (See Appendix D) It was subjected to control on the assumption that the spread of mistletoe could be halted and the infested trees replaced by forthcoming clean seedling growth. Now that the largest part of the program is over follow-up action at periodic intervals must be continued to assure every possibility of success.

3. Reestablishment of Native Species: Where research may determine that exotic plants can be discouraged by control or by seeding of native plant species, the necessary actions shall be taken. Seeding shall also be practiced if necessary to reestablish native plant species. Wherever possible, re-seeding and/or transplanting shall be done by methods which do not leave mechanical scars on the landscape.

D. Wildlife and Wildlife Observation Opportunities: Management of the wildlife resource shall follow the guidelines presented in this plan and the Long Range Wildlife and Range Management Plan approved for this area on August 8, 1965. This effort also must be geared to continuing research.

1. Resident Species: Proper management of the birds, rodents and other mammals which live year around within the Monument is automatically a product of good management of the vegetative cover. No problems in this respect are known or anticipated. The small animal population is healthy and a steady source of enjoyment to area visitors.

2. Migratory Species: For the many migratory species listed in Section IIID, Craters of the Moon is only a summer and fall home. Their future is largely linked with human activities outside the Monument. For this reason it is imperative that close working relationships be maintained with the Bureau of Land Management, the Idaho Fish and Game Department, the Forest Service and local landowners. If such animals as mule deer, antelope, wapiti (elk), coyote, bobcat, cougar, black~~ear~~^{foot}, and migratory birds are to persist, the "total environment", (of which Craters of the Moon is only a part) must be managed with this in mind.

Craters of the Moon can best carry out its role through management of original vegetative conditions. It may also function as a research area where others may study wildlife populations which are free of competition from domestic livestock. ✓
p. 4, 18

3. Reintroduction of Extirpated Species: Reestablishment of bison, grizzly bears or wolves is obviously not practical. However, there is reason to believe that bighorns might be restocked with success. In other parts of the United States such efforts have been rewarding. Research must determine the feasibility and best methods of doing so. This should be a cooperative effort with the Idaho Fish and Game Department, BIM and the Fish and Wildlife Service. ✓

Craters of the Moon has an excellent release site in the Little Prairie area where all bighorn requirements seem to be met. Some risk is involved: Whether or not they would accept the area as a home range is problematical.

In the 1800's the Rift area was winter range for them. It is now summer range for deer. Year around forage conditions are obviously available, yet this is no guarantee they will not leave.

4. Control of Excess Populations: To date, all concern in this regard has involved mule deer. Because their migration route is rather specific, the herd could be easily reduced in normal years by a two-week extension of the local hunting season. If this proved administratively difficult the animals could be hazed out of the Little Cottonwood area by three or four Service personnel. In late October some 200 to 300 deer harbor in three Sections of land there. Through cooperation with the State, hunters could be stationed outside the boundaries in advance to accomplish the reduction in one operation. The extended season is much preferred, however, as it does not involve a "firing line."

Whatever the chosen method might be, it should not become an annual harvest. This has proven in other areas to be an effective method of upsetting migrational instincts of the herd. Better to drastically over-harvest every five years or more. In this way the migration pattern can be retained.

}
Stimulate
Natality

5. Observation Opportunities: Careful attention must be paid to the distribution and daily movements of wildlife to assure they will not be disturbed in such a way that visitor observation opportunities will be reduced. For example, we must know where resident deer along the loop drive feed, bed and water. Mistletoe control or other plant manipulation

should be managed so that not all of the cover or forage requirements of the animals are removed. Parking areas or interpretive exhibits should not be placed where they would intersect regular deer trails and cause the animals to choose an alternate route which would not permit visitor observation. Food and cover requirements of other birds and mammals should similarly be kept in mind.

In any reduction program control site selection must be practiced. This simply requires that any shooting or other disturbance of the wildlife be done someplace other than along the visitor circulation routes. In parks where this has been ignored, herds of deer or elk have established a strong fear association with the road system. Visitor enjoyment suffers drastically. Particularly at Craters of the Moon, the job of reduction should never be so large that it cannot be done well away from areas of visitor observation.

Deer can be baited with salt blocks to provide visitor observation. Differential distribution can be controlled in this manner also. However, neither appears desirable at Craters of the Moon. nw 10

E. Wilderness Management: (See Master Plan Page 3) Tutimaba Wilderness is among the most pristine and unaltered wilderness areas within the National Park System. On the eve of its formal designation as a unit of the National Wilderness System it is visited by less than a hundred persons per year. Most of these visitors are rather sophisticated in their outdoor habits and tend to leave very little evidence of improper use. It is

the obligation was well as the opportunity of the Service to circumvent improper uses before they occur. Management planning must precede the increased use which formal designation of the Wilderness will generate.

1. Day Use: No point in the Wilderness is more than 6 miles from public roads. This means that a fair hiker can reach any part of the area and return to his car the same day. Most of the interesting features are within three miles of a road. The Rift zone is particularly easy traveling as it is lined with cinder cones, rather than rough lava, and is well supplied with deer trails. A few old wagon tracks go as far as the Sentinel and Yellowjacket Waterhole. Because of this and because overnight use is much more disturbing to any area, visitors will be encouraged to enjoy the area on a day-use basis.

2. Overnight Use: People interested in exploring the rougher and more distant portions of the Wilderness, or spending several days in certain sections, will be given camping permits. Overnight use shall be restricted to remote parts of the area which cannot be reached in a short walk of an hour or so. Camping locations will be established in the following vicinities. Specific sites shall be so designated that camping does not occur directly on or in an important natural feature:

- a. Tree molds in Section 34 T1N R24E
- b. Sheep Trail Butte - Vermillion Chasm
- c. South side of The Sentinel
- d. Amphitheater Cave
- e. Tree molds in Sections 15 and 23 T1N R25E
- f. Round Knoll

Ranger patrol of the Wilderness will be required as use increases. ✓
Whenever possible large parties such as Boy Scouts and other youth groups should be accompanied at least part way by a ranger.

3. Horse Use: Horses and pack animals can be taken from Broken Top to Little Prairie and the grass community south of The Sentinel before encountering difficult lava terrain. This amounts to about a one-hour trip or a two hour round-trip ride. Thus there is no realistic need to use animals on an overnight basis in the Wilderness. If necessary, special regulations shall be established limiting pack and riding stock to daytime use only. Overnight use would force heavy demands upon the few dwindling waterholes, as no other source of water is available. Other damaging effects of keeping horses overnight are unjustifiable in an area as small and accessible as Tutimaba Wilderness. Large parties can use horses on a drop load basis with no hinderance to their activities.

4. Public information: Concerted efforts should be made to educate visitors in ways to use the Wilderness on a non-consumptive basis. The goal is the type of use which leaves no visible evidence of the party's visit -- no fireplace, no trash, no camping structures. Signs on trails entering the area, booklets distributed to interested visitors, and personal contact by patrolling rangers can all contribute to the effort.

5. Development: Trails should neither be built nor maintained in the Wilderness. The area is essentially flat and well supplied with deer trails. A constructed trail route would create channeled traveling rather than the dispersed type of use desired. Campsites need only to be designated, not "built." Constructed facilities would compromise the "mood of wild America" which the area is intended to preserve.

6. Waterholes: Scientists of the region agree that the area has been in an arid cycle for the past century. As mentioned in Section IIIA and V, many of the waterholes appear to be drying up. We are certain that this trend has continued since 1920. While there appears to be no immediate danger of their complete disappearance, caution in their use is justified. It appears reasonable to seek a special regulation prohibiting their use by visitors. This should not hinder visitor use of the area in any way. The shallow pools are usually contaminated with insects and other natural refuse. Human use to date has been predominately from curiosity rather than necessity. They are also difficult to locate and a hiker would be foolish to depend on them for his needs. Without protection by regulation, however, use by wilderness campers for dishwashing and livestock could rapidly cause any of them to go dry. The waterholes are unique natural features worthy of perservation. The small quantity of water available in them is also very important to wildlife -- particularly to birds.

Waterholes found dry in 1965 include Registration, Doves, Big Sink and Yellowjacket. With the exception of those near Round Knoll, all others appeared to be at a low ebb.

F. Water Supply: In general, there is no immediate concern with the domestic water supply. From a management standpoint, the main consideration is to protect the two small drainage systems from fires and livestock trespass.

In time, it may be necessary to supplement the water supply with additional diversion structures. It is also possible that a well drilled at the forks

of the two branches of Little Cottonwood Creek might produce much of the water which disappears from the streams. An additional spring will be made available for use when the Creek Lode mining claim is acquired.

VI RESEARCH

A. Research Accomplished: Biological research by Egglar, 1941; Hugie et al, 1964; Passey et al, 1964; and Tisdale et al, 1965 is listed in Section IV of this plan. These studies give general information on plant communities as related to soil conditions.

Dr. William Baker of the University of Idaho has been working for some time on a plant list of the area. Efforts are being made to encourage completion of the project. A tentative list of mammals was prepared in 1956 by Professor Earl J. Larrison, also of the University of Idaho. Mr. Larrison apparently plans no future studies in the Monument.

Former Seasonal Naturalist Donald S. Horning is nearing completion of "Insect Life and Ecological Relationships on a Lava Landscape." This is a Master of Science Degree project at the University of Idaho. Mr. Horning performed his field work at Craters of the Moon in 1964 and 1965 under grant by the Craters of the Moon Natural History Association.

Geological research of the area is covered quite well in two studies:

Murtaugh, John G. 1961, Geology of Craters of the Moon
National Monument. Masters Thesis, University of Idaho

Stearns, H.T. 1928. Geology of Craters of the Moon.
Unpublished manuscript. NPS Files.

B. Research Needs: A full analysis of research needs must await reconnaissance in several areas of study. Until then we cannot fully identify all potentialities. The following list must be considered a preliminary sketch:

1. Checklist of Plants. A complete list has never been made. This should include completion of the herbarium collection. Little has been done with spring plants which are usually gone by the traditional summer collection period. ✓

2. Short-Cycle Plant Succession. The effects of fire, insects, plant diseases and other temporary factors upon plant communities. ✓

3. Mule Deer Management. Causes and effects of recent population increases within the Monument. Distribution and migrational trends. Range trends and plant utilization measurements. Establishment of exclosures. ✓

4. Archeological Survey. A professional survey by archeologists of Idaho State University appears most promising. They have made many recent studies in this region. Dr. Earl Swanson of ISU feels that some age-dating of recent lava flows may be possible through archeological techniques. Many known sites need to be evaluated. ✓

5. Bird Ecology. With checklist. ✓

6. Waterhole Management: Climatic and physical factors which influence the occurrence or disappearance of waterholes. Influences of wild animals and man. ✓

7. Dwarfmistletoe Control Study: Effects of current methods of controlling dwarfmistletoe in limber pine. ✓

8. Animal Ecology: With Checklist. Particular reference to activities of small mammals in the semi-barren lava flows as related to phenological factors. ✓

9. Historical Conditions. A re-check of historical references and ✓

other techniques which can provide further knowledge of biological conditions of a century ago.

10. Ecological Abstract: A resume of the above studies by qualified scientists, with reference to further management and/or research needs.

Portions of the above studies may be accomplished by Monument personnel as their interests and special abilities permit. The bulk of research will be accomplished by local universities under the direction of the Service. From one to two thousand dollars per year is being set aside by the Natural History Association for such work.

V ACTION PROGRAM

The following resources management actions are currently being taken or will be in the near future. While they will benefit from forthcoming research and further management experience, they need not be postponed until such is obtained. Beginning applications of some of the new management measures will amount to small scale testing.

A. Management of Geologic Features

1. Install protective walks, ladders, enclosures or barriers in the tree mold and Spatter Cone area and other locations as increased public use demands.
2. Complete "loop" trail systems in the North Crater Flow interpretive trail, the Indian Tunnel trail, and possibly between Beauty and Surprise caves if a desirable route can be found.
3. Continue all public information efforts which will reduce specimen collection and vandalism. Off-site wintertime talks in surrounding communities must continually be presented.
4. Obtain additional seasonal ranger positions so that roving patrols can be maintained daily during the summer season in the Spatter Cone and Cave areas, with intermittent patrols elsewhere.
5. Move the campground as called for in the Master Plan.
6. Adhere to a day-use principle in the primary geologic area.

7. Seek establishment of State Laws which will permit prosecution of rock collectors and vandals in the local Justice Court.

B. Landscape Protection

1. Continue obliteration of old roads and saw-cut stumps.
2. Close out and landscape existing cinder pits at Inferno Cone and the headquarters area by 1970. Arrange to obtain cinders from BLM pits off the Monument. 30 -
3. Maintain barriers along the road where needed to prevent visitors from driving onto open cinderfields.
4. Carefully evaluate any plant pest control programs to assure that cutting and mechanical disturbance is practiced only when absolutely necessary, and then with all consideration given to protection of the original scene.
5. Use of earth moving equipment for fire break construction, or travel off established roads with vehicles to suppress fires or pursue other management efforts, shall not be permitted.

C. Management of Vegetation

1. Following necessary public information efforts, and in keeping with guidelines of this plan, permissive burning of natural fires shall be applied within the zone shown in Appendix E. Unnatural fires and all fires in the mandatory control zones should be suppressed.

2. Continue necessary follow-up action within the present dwarf-mistletoe control zone. Withhold expansion of the program until sufficient time has passed to fully judge results of the current effort.

3. Continue periodic forest pest inspections by Service personnel and other cooperating agencies. Initiate pest control efforts only after thorough evaluation by qualified research, and then in keeping with guidelines of this plan.

4. Employ reseeding as a means to reestablish native plants or suppress exotic plants where conditions require.

*Mosses
clarification*

5. Continue hand eradication of mullein within the headquarters-loop drive vicinity.

D. Wildlife and Wildlife Observation Opportunities:

1. Initiate range trend and deer utilization studies in 1966 to provide a measurement of potential overabundance of deer. Continue fall counts in the Little Cottonwood area.

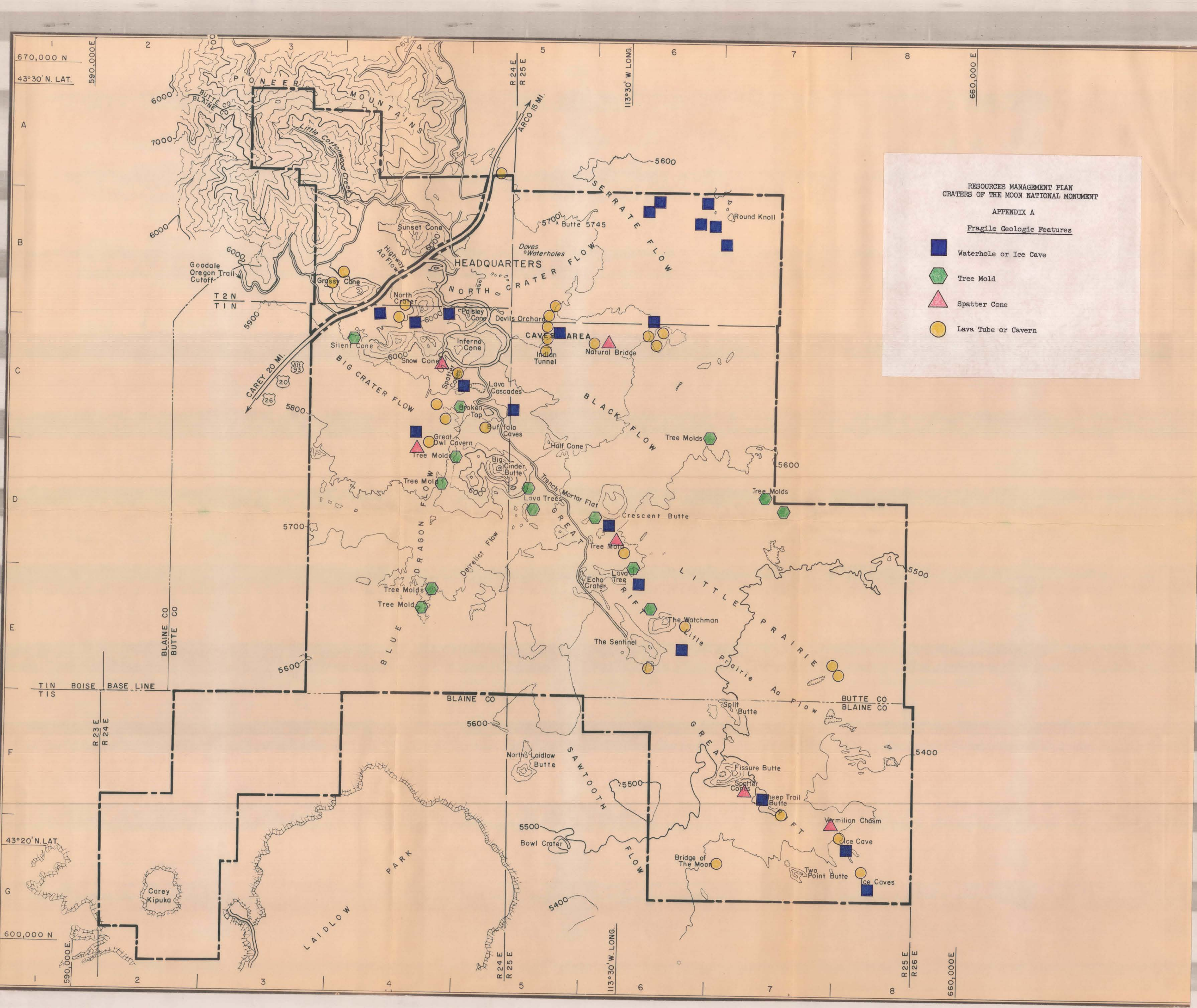
2. Continue close cooperation with other agencies to maintain healthy populations of migratory birds and mammals in the Monument and surrounding region.

3. Continue efforts to reestablish bighorn sheep in the Little Prairie area.

E. Management of Wilderness:

1. Obtain a special regulation prohibiting use of lava waterholes for other than emergency purposes.
2. Visitors to the Wilderness shall carry out all refuse not burned in permitted fires.
3. Designate certain camping areas for overnight visitors as called for in Section VE, but encourage use on a day-time basis.
4. Seek regulations prohibiting overnight horse or pack animal use if forthcoming use patterns require.
5. Prepare booklets and other public information media on non-consumptive use of the wilderness.
6. Encourage visitor dispersal and self-determination in the Wilderness. Construct no trails or other facilities.
7. Permit campfires only in designated overnight camping areas and only in periods of low fire hazard. Encourage use of lightweight stoves which will not require cutting of the sparse limber pine forests.

F. Water Supply: Within the next decade the chief effort will be protection of the watershed from fire and livestock grazing. Exploration of well locations should precede construction of the Little Cottonwood Campground.



RESOURCES MANAGEMENT PLAN
CRATERS OF THE MOON NATIONAL MONUMENT

APPENDIX A

Fragile Geologic Features

- Waterhole or Ice Cave
- Tree Mold
- Spatter Cone
- Lava Tube or Cavern

Geology of
CRATERS of
the **MOON**

Idaho

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Looking northerly from Big Cinder Butte along the Great Rift with its chain of spatter and cinder cones. Pioneer Mountains visible in background. Photograph by Franklyn N. Hambly, National Park Service.

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**GEOLOGY OF THE CRATERS
OF THE MOON
NATIONAL MONUMENT
IDAHO**



by Harold T. Stearns

ABOUT THE AUTHOR AND THIS BOOKLET.

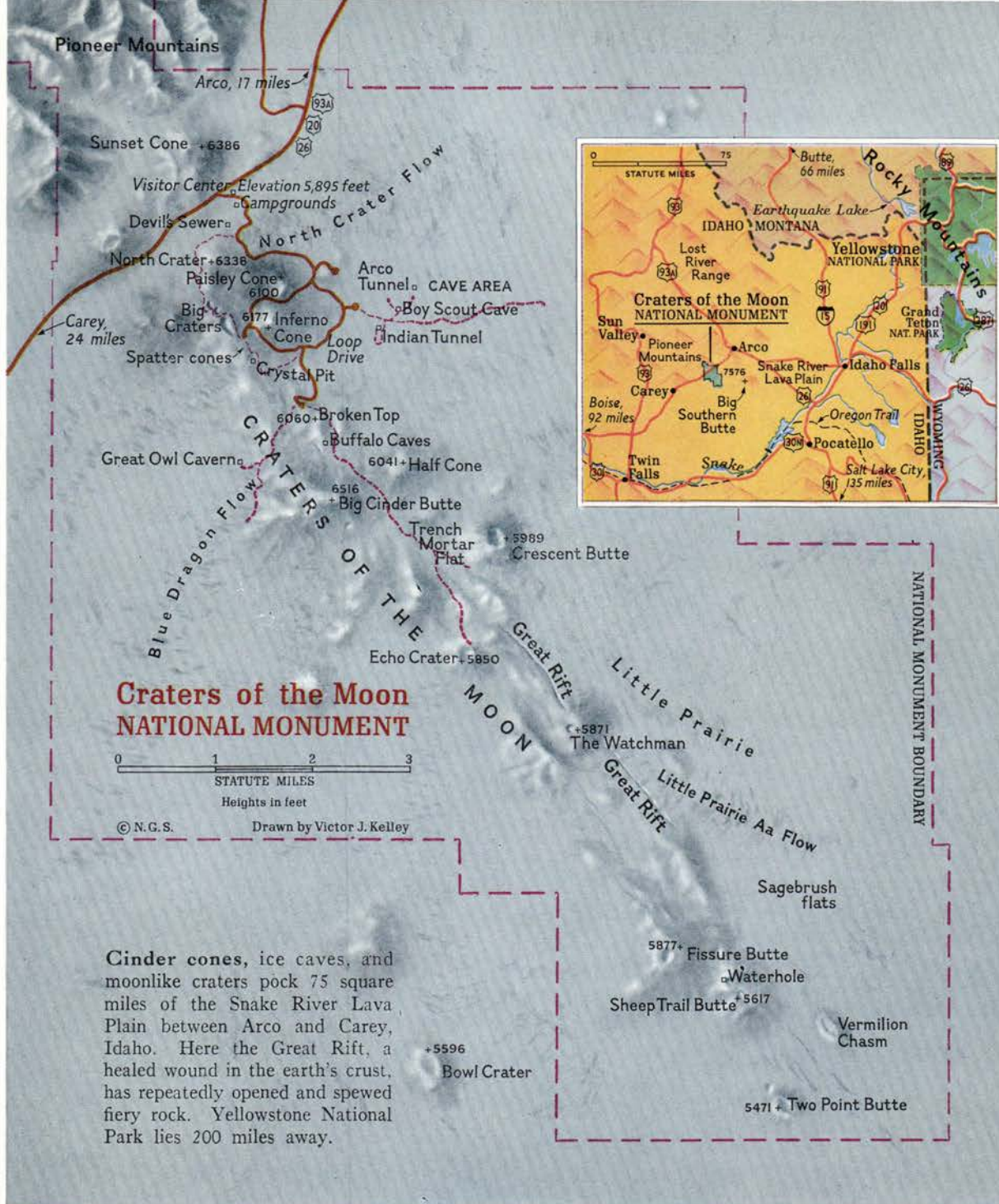
The original survey of the Craters area was started by the author in 1921 for the U.S. Geological Survey. In 1923 he wrote a very favorable report to the National Park Service describing the volcanic features and recommending that steps be taken immediately to preserve them as a National Monument. His report and recommendations were forwarded by the Park Service to President Coolidge. The President commended the author for his recognition of the need for preserving the unique formations and, on May 2, 1924, proclaimed 39 square miles to be the Craters of the Moon National Monument.

In 1926 the survey was completed in cooperation with the Idaho Bureau of Mines and Geology and a popular summary of the geology was published by them in 1928 as Bulletin 13. The Bulletin was soon out of print but was reprinted in July 1930 with slight changes as "A Guide to the Craters of the Moon National Monument, Idaho" by Caxton Printers at Caldwell, Idaho. It included a description of the fauna and flora and ran through six editions. In 1938 a colored geologic map of the Monument made by the author was published in "Geology and Ground-water Resources of the Snake River Plain in Southeastern Idaho": U.S.G.S. Water Supply Paper 774. Detailed descriptions of the various lava features have been released in manuscript form in the open files of the U.S.G.S. in Boise, Idaho and in Washington, D.C. (See Circular 448, item No. 133, 1960) The present booklet is based on the old "Guide" with new illustrations and current data.

The author has studied volcanic terranes over a period of 40 years in many parts of the world. He mapped the geology of the Hawaiian Islands, including the active Kilauea and Mauna Loa volcanoes. After 25 years of service in the U.S. Geological Survey, he resigned to become a Consulting Engineering Geologist specializing in construction projects and water development in volcanic terranes. He now resides in Hope, Idaho.

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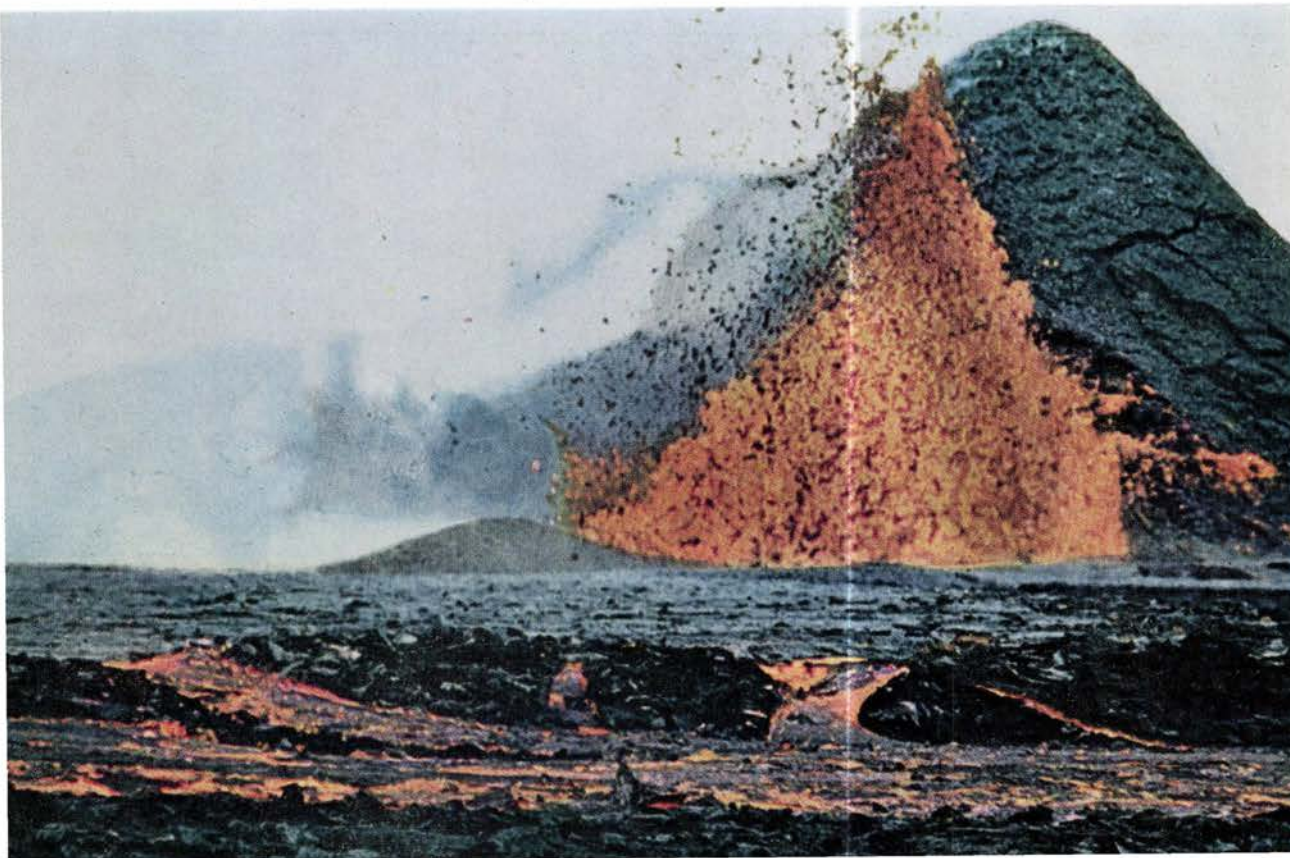
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Crystal Pit and adjacent spatter cones were made by firefountains erupting along a fissure. Photo by Peter G. Sanchez, National Park Service.

Firefountain building a spatter cone along a fissure on the slopes of Kilauea Volcano, Hawaii, January 28, 1960. The glowing lava is typical pahoehoe with crustal cakes floating on its surface. Photo by Carter and Rackle, Honolulu.



INTRODUCTION

"An area of about 60 miles in diameter, where nothing meets the eye but a desolate and awful waste, where no grass grows nor water runs, and where nothing is to be seen but lava."¹ Undoubtedly Irving's description has reference to the area now known as the Craters of the Moon region of Butte and Blaine counties, Idaho. About 39 square miles of this unique volcanic area was proclaimed the Craters of the Moon National Monument by President Coolidge on May 2, 1924. It was subsequently increased to 83 square miles. It is administered by the National Park Service of the Department of the Interior. The address of the Superintendent of the Monument is Arco, Idaho.

The Monument is reached by a drive of 20 miles from Arco southwest along U.S. Routes 93A-20-26. It is easily accessible to tourists on the way to or from Yellowstone National Park. Upon entering the Monument the road leaves the dusty sagebrush desert and enters an area of barren black cinders and lava. Here it winds among the smooth cones and across strips of rough fresh-looking rock. The similarity of the dark craters and the cold lava, nearly destitute of vegetation, to the surface of the moon as seen through a telescope gives to these peculiar features their name. The Monument comprises the most interesting and recent part of a vast lava field that covers hundreds of square miles and merges westward into the Columbia Plateau. This plateau covers about 200,000 square miles and contains 26 cubic miles of lava.

A marvelous view of this desolate lava waste is obtained from the summit

of Big Cinder Butte, which rises to an altitude of 6,516 feet and ranks among the largest purely basaltic cinder cones of the world. To the east stretches barren black lava until it fades into the desert haze. Nothing breaks its monotony except one group of grass-covered cones which were not inundated by the floods of lava and which now stand together as a yellow island in a sea of black. Farther east rises Big Butte, the sentinel of the Snake River desert. A little beyond and to the northeast of it, seeming to float in the blue haze, are two smaller peaks known as the Twin Buttes. These peaks have been majestic watchmen on the plain since the first eruptions of lava in the Monument.

To the southeast from Big Cinder Butte extends a double line of cinder cones, many of them grass-covered and all of them vents of volcanic flows which unite farther south into one great lonely and uninhabited field of lava. Black Top Butte, the farthest in this march of cones, lies approximately 11 miles southeast of Big Cinder Butte. Still farther away are yellow grass-covered cones, and in the distance are barely discernible the snow-covered Portneuf and Bannock mountains.

Extending southward from Big Cinder Butte is a chaos of cinder crags and jagged lava, which reaches as far as the high cinder cone called North Laidlow Butte, eight miles away. Half a mile beyond this cone is Little Laidlow Park, a grass-covered field of ancient lava, appearing pale yellow under the bright midday sun. Farther away on the plain are low lava domes, and in the extreme distance, beyond Snake River,



Airview of an extensive pahoehoe lava flow showing numerous sink holes caused by the collapse of the crust as the lava drained away through lava tubes to the lower margin. Photo by D. C. Ochsner, National Park Service.

are pale blue mountains along the Idaho-Utah line.

To the west for about 6 miles the lava flowed against the Pioneer Mountains, filling the valleys as if they were bays and leaving the ridges like projecting headlands in a black sea. Black and barren as it is, the lava surface has a weird scenic charm.

To the northwest there are crater pits, spatter cones, cinder cones, and lava flows, massed along the Great Rift. Many of the cinder cones are brilliant red at noon but slowly change to purple by sundown. On the tops of many of them are discernible yawning crater pits, which are especially beautiful under the lengthened purple shadows of evening. Beyond this chaotic display of volcanic features rise the impressive Pioneer Mountains, covered with grass and streaked with small groves of quaking aspen, golden with autumn foliage and snuggled away in twisted ravines and canyons. Farther north are the snow-clad Sawtooth Mountains, the pride of all Idaho. This grand array of hills and mountains presents an inspiring scene and toward

evening becomes pale and soft and velvety, like a staghorn in spring. To those who tarry long, these hills are "never the same, yet are always the same through each changing."

GEOLOGY

These are the Craters of the Moon as they appear today; let us turn back the pages of stone in the geologic history of this region to the time before any lava had appeared in southeastern Idaho, when the Pioneer Mountains of ancient rocks, then higher than they are now, projected southward into the wide valley of the ancestral Snake River. All the rivers—Big Lost River, Little Lost River, Birch Creek, and the other streams adjacent to the area—flowed southward within the mountain canyons and joined the ancient Snake. Today these rivers sink into the lava plain at the foot of the mountains and find their way underground into the Snake River through numerous crevices and cavities in the lava.

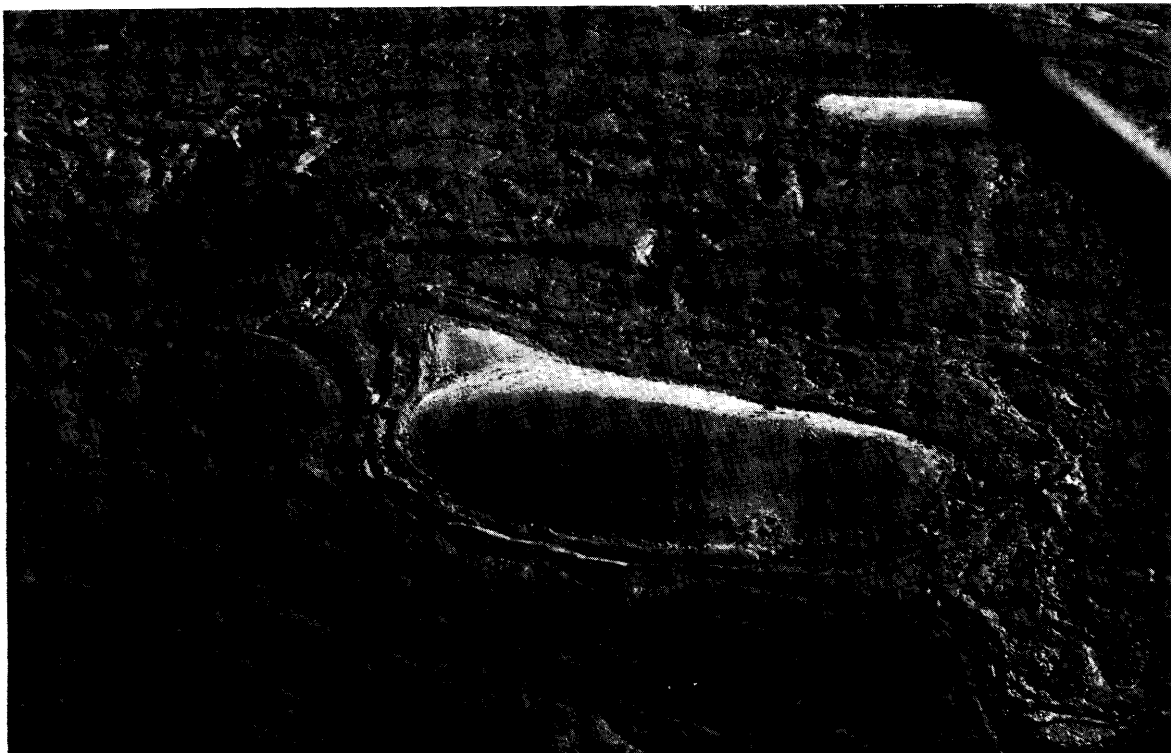
The Pioneer Mountains and their foothills slumbered peacefully and un-

disturbed except by stream erosion until one day, long before Egypt had a name, a tremendous fissure, now known as the Great Rift, opened on their slope. With this earth rifting there occurred a volcanic eruption that built up a long line of cinder cones, and lava flowed southward and eastward, cooling into thick, jagged flows, consisting largely of broken blocks. "Frozen" in some of these lava blocks are large and small fragments of granitic rocks that were broken from the roof of the lava reservoir and floated upward in the molten lava during the eruption. The lava issued at a temperature of about 2,000° F., which was too low to remelt the granitic inclusions; hence the white fragments retain their original characteristics. Numerous eruptions occurred during this epoch, but most of the flows and cones then formed are now buried by later flows. Remnants of these old cones, broken by faulting, and weathered into hoodoo pinnacles of cinders and spatter, form the Devil's Orchard and the field of crags south of

Big Cinder Butte. In these crags occurs obsidian, or volcanic glass, which the Indians quarried to make arrow points and other implements.

For a long time the Great Rift seemed to be healed; but volcanic activity was only dormant. Eruptions broke out again with renewed vigor, and many of the large cinder cones in the chain that stretches southeastward through the center of the Monument were formed. To this second epoch belong Sunset, Grassy, Silent, Big Cinder, Fissure, Split, and numerous other cones on the Great Rift. Most of their lava has been buried by later flows, but the cones rise above the later flows as islands. (See end tables for a list of the cinder cones giving their height and location.) The volcanic outbursts were spasmodic in occurrence but probably followed one another at short intervals. Often more than one cone was formed during a great eruption, and there is evidence that some of the cones were made by several eruptions occurring at the same place. All these

Great floods of molten lava, now congealed in giant waves, nearly inundated Round Knoll, an ancient cinder cone, which now stands as a yellow island in a sea of black.
Airview by D. C. Ochsner, National Park Service.







Billowy pahoehoe near Indian Tunnel resembles the hide of an elephant. Photo by D. C. Ochsner, National Park Service.

manifestations of internal unrest continued throughout centuries, and the Great Rift was reopened again and again. Thus it became a great zone of weakness in the earth's crust and the center of many earthquakes.

The third and last epoch of eruption followed upon the heels of the second and may have been closely connected with it. During this epoch all the barren black lavas that are found in the area were emitted. North Crater, which is visible from the highway, was reopened and gave vent to a large billowy lava flow that moved northward and then eastward. This flow is crossed by the road leading into the Monument. Big Craters gave vent to four flows during this epoch—one to the northeast, one to the northwest, one to the west, and one to the southeast. Coincident in time with the last eruption of Big Craters the line of spatter cones along Crystal Fissure was formed, and lava flowed eastward and westward from them. With the

subsidence of the lava in the Great Rift after this eruption numerous areas on the rift collapsed, forming a chain of pit craters. Big Sink Water Hole is one of these pit craters.

Big Cinder Butte again broke open and gave vent to a short lava flow on the north side. Two other outpourings of lava occurred in the area half a mile northwest of this breach, but the eruptions at these vents did not build cinder cones. Lava was also poured out at Indian Tunnel, at the Natural Bridge, and at Needles Cave in the area east of Inferno Cone.

In the central part of the Monument the old cinder cone called The Watchman opened, and lava flowed out quietly from the northwest and southeast sides. Numerous other lava flows that cannot be described here occurred in the area during this time. Altogether about thirty-five cones and vents and thirty different lava flows belonging to several epochs are found in the Monument. Many others were probably

← **Spatter cones** in the foreground and Big Cinder Butte in the right background indicate by their alignment the position of the Great Rift, a fissure in the earth's crust which has repeatedly erupted to form the Craters of the Moon. Photo by D. C. Ochsner, National Park Service.

formed but have since been buried. (See end tables for the approximate eruptive sequence of the principal lava flows in the area.)

SOURCE OF THE LAVA

The structure of the earth and the depth from which lava originates have been determined with fair accuracy from the rate of transmission of earthquake waves recorded at various seismological stations. A section of the earth is shown in the diagram on page 7. The sedimentary layer and its associated lava flows average about 2 miles in thickness on the continents. An irregular more massive layer of granite, about 20 miles thick, lies under the sedimentary layer. The sedimentary layer may be more than 5 miles thick under the Snake River Plain because the plain has been a sinking block in which sediments and lavas have been accumulating for a very long time. By contrast the Pioneer Mountains in the north end of the Monument are on a rising block of the earth's crust and close by is the Salmon River Basin where granite is exposed at the surface. The boundary between the sinking and rising blocks is approximately along U.S. Route 93A between Arco and Carey, Idaho.

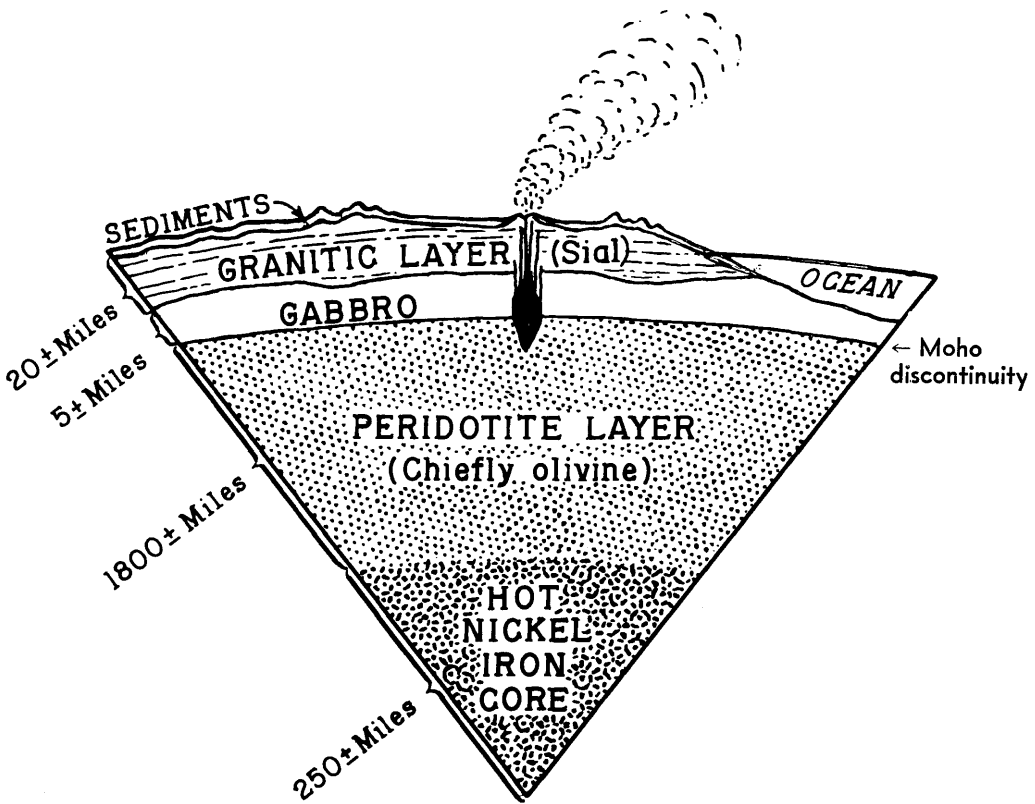
A gabbro layer 5+ miles thick underlies the granite layer. Gabbro is a coarse grained silica-poor rock commonly called black granite. It has the same composition as basalt but has a coarse grained texture caused by cooling slowly under the heavy weight of the overlying crust, just as granite is the coarse grained equivalent of rhyolite, the silicious lava common in Yellowstone National Park and in Big Southern Butte.

The Moho discontinuity is the break between the gabbro and peridotite layers. This break has gained publicity in recent years as a result of the at-

tempt to drill to it from aboard ships. Earthquake waves behave differently when they pass from the gabbro layer to the peridotite layer, a condition believed to be caused by plastic or liquid material below the discontinuity. Rocks are at high temperatures and under great pressures at a depth of 25 miles so that a slight decrease in pressure may cause the gabbro to liquify. The liquid magma may then rise along fissures and erupt at the surface as basalt. This is what happened repeatedly along the Great Rift and elsewhere in southern Idaho in late geologic time. The eruptions have built the extensive Snake River lava plains. The relief of pressure which causes an eruption apparently is related to adjustments in the earth's crust brought about by changes in its form. Adjustments never cease and, at times of slippage, give rise to earthquakes. The rate of change is cyclical in geologic time so that some periods are times of mountain building and other periods are times of slow sedimentation. Southern Idaho at present appears to be near the end of one of the great epochs of mountain building; hence has a declining rate of volcanic and earthquake activity. However, earthquake epicenters in historic time lie close by at Hailey and more recently at Hebden, Montana on the outskirts of Yellowstone National Park.

NONVIOLENT ERUPTIONS

Many visitors to the Craters of the Moon talk about the tremendous catastrophe or awful convulsion that must have occurred in the area, but the writer found no evidence of any great explosive eruption such as occurred at Krakatoa, near Java, in 1883; at Vesuvius, in Italy, in 1906; or at Katmai, in Alaska, in 1912—tremendous explosions which spread volcanic dust for hundreds of miles. Such eruptions as



Hypothetical section showing the origin of the Great Rift eruptions in relation to the layers in the earth.

these usually cause great loss of life and property. The dust from the eruption of Krakatoa was carried by winds around the earth and fell on the rooftops in London. The brilliant sunsets that followed the eruption of Katmai were caused by particles of volcanic dust in the atmosphere. The character of the ejecta in the Monument, however, shows that the effects of the eruptions at the Craters of the Moon were relatively insignificant and were confined to the area inundated by the lava flows or adjacent to the cinder cones. The volcanic outbreaks in the Monument were all of the so-called quiet type, like those that occur at intervals at Kilauea and Mauna Loa, in Hawaii where thousands of persons visit the eruptions.² Should a similar eruption occur in the Craters of the Moon to-

morrow, it would be possible to stand with safety less than half a mile from the windward side of a cinder cone in eruption and to approach within a few feet of a lava flow in motion.

The mechanism of a volcanic eruption of the type that occurred in this area may be compared to the opening of a beer bottle. The liquid remains quietly under pressure within its bottle walls, but when the cap is removed the pressure is released and the included gas expands, causing the contents to foam and to overflow the neck of the bottle. The first foam that runs over consists of large bubbles, but as the foaming diminishes the bubbles decrease in size, and some of the liquid runs out. However, all of the gas does not escape during the foaming period, for gas will continue to rise in the



A "frozen" cascade of pahoehoe east of Surprise Cave. Photo by H. T. Stearns.

liquid for a considerable time thereafter. Like the fluid in the bottle, the magma, as the molten lava with all its included gases is called, rests in an underground reservoir surrounded by strong rock walls. It may remain in this natural container at or about the same place for a long period of time, until some force cracks open the earth's crust above the reservoir, thereby releasing the included gases. The weight of several miles of the earth's crust is immense, but as the molten magma ascends in the crack the pressure upon it becomes less and less. The included

gases continue to expand as the magma rises, and when it reaches the surface there may be a tremendous foaming and frothing of the lava column. It is during this period of foaming that the cinder cones are built, the cinders being the hardened froth. After the period of intense foaming the gas bubbles decrease in size, and the heavier lava clots or spatter are thrown out. Almost concurrently the lava flows away from the newly formed crater, either over the rim or through a channel in the side of the cone. Like the liquid beer after the foaming period,



Pahoehoe in places breaks up like slush ice on a river in spring. Photo by H. T. Stearns.

the lava still contains considerable gas, and it is the escape of this gas as the lava hardens that forms the vesicles, or bubble-shaped holes in the lava.

TYPES OF LAVA

Many kinds of lava have been poured out on the surface of the earth, but they all fall into three main classes or types. One type, known as rhyolite, is poor in iron but rich in silica and consequently light-colored. It is the common lava of Yellowstone Park, and this rock and its decomposition products give the magnificent colors in the Grand Canyon of Yellowstone River. Another type of lava, known as andesite, is of intermediate composition, containing moderate amounts of both iron and silica, and is usually gray. The lava extruded from the volcano of Lassen Peak, California in 1915 is an andesite. The third type, which is rich in iron and poor in silica, is called basalt. This is a dark-colored rock. It covers the Snake River Plains, forms the rim rock along Snake River, and is the rock commonly known as lava in the Northwest. It is the only

type of lava known to occur in the Craters of the Moon.

Because of the numerous queries of visitors to the Craters of the Moon as to the composition of the lava, an analysis, made by the United States Geological Survey, of a specimen of basalt collected by I. C. Russell near Big Cinder Butte is given below:

ANALYSIS OF RECENT LAVA FROM THE BIG CINDER BUTTE FLOW, CRATERS OF THE MOON NATIONAL MONUMENT, IDAHO

[Analyst, W. F. Hillebrand.]

	Per cent
Silica	51.14
Titanium dioxide	2.41
Zirconium dioxide	.12
Alumina	13.95
Chromic oxide	None
Vanadium trioxide	Trace
Ferric (iron) oxide	2.15
Ferrous (iron) oxide	12.97
Manganous oxide	.44
Nickelous oxide	Trace
Calcium oxide	6.56
Strontium oxide	Trace
Barium oxide	.25
Magnesium oxide	2.21
Potassium oxide	2.33
Sodium oxide	3.59
Water below 105° Centigrade	.12
Water above 105° Centigrade	.22
Phosphoric oxide	1.59
Carbon dioxide	None
Chlorine	Trace
Fluorine	.10
Iron disulphide	.15
Less oxygen computed in place of fluorine	100.30
Total	100.26
Specific gravity 2.907 at 24° C.	

PAHOEHOE AND AA LAVA FLOWS

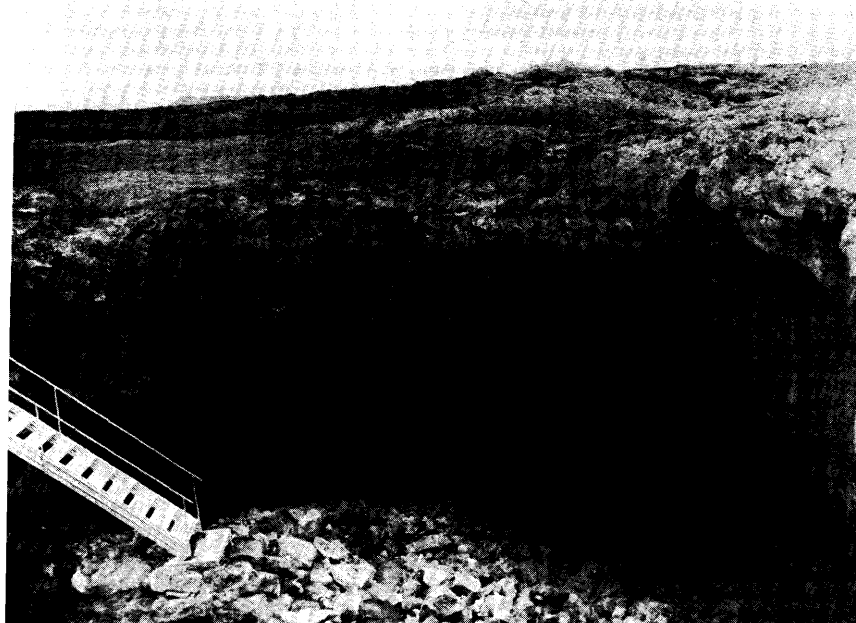
In physical characteristics the lava flows that occur in the Craters of the Moon belong to two distinct types known by the names of pahoehoe (pah-ho'ay-ho'ay) and aa (ah'ah). These two Hawaiian words have been adopted as scientific terms to describe the two types of lava flows.

Pahoehoe, which covers about half the area of the Monument, is a billowy, ropy type of lava that is filled with caverns. Its shiny blue glassy crusts make some of the flows beautiful in brilliant sunlight. The ropy and wrinkled surfaces of the pahoehoe are due to the hardening of a thin crust or scum on the lava flow while the crust is being pushed forward by the flowing lava below. The motion causes the

scum to wrinkle and fold very much like molasses poured from a jug on a cold winter day. The numerous caverns that are found in the Craters of the Moon all occur in the pahoehoe lava. They are formed within the flow itself by the hardening of the surface of a lava stream. As the flow continues the side walls also stiffen and a tube is formed. The main tube forks and re-forks and the lava is conducted without much loss of heat to the advancing margin of the flow through this set of ramifying tubes, which extend away from the vent in a sort of great subway system. As the slope of the land is not very steep in the Monument, only the upper or source ends of the tubes were drained out when the lava ceased flowing. A list of the principal lava caves and their location is given in the end

The rough, bristling, jagged kind of lava is known as aa. Walking over such rock is extremely slow and hazardous. View of the Northeast lava flow from Big Craters Butte. Photo by H. T. Stearns.





Entrance to Indian tunnel, the largest and most accessible lava tube in the Monument. Photo by D. C. Ochsner, National Park Service.

tables. Indian Tunnel, Great Owl Cavern, and Buffalo Caves show lava stalactites formed by the dripping of the hot lava from the roof. On the walls are hardened trickles of lava. The narrow ledges parallel to the floor of the caverns are the temporary levels of a subsiding river of lava. On the floor the last stream of lava, with its ropy and twisted surface, is usually visible. When the lava flows out of the tube

there are many portions of the roof that are unstable and collapse or are shaken down by earthquakes accompanying some of the later eruptions. The natural bridges are small remnants of the tunnel roof that are left standing; the portions that are roofed over for longer distances form the caverns. The location and size of the large bridges are given in the end tables.

While chemically like pahoehoe, aa

Natural bridge—remnant of a tunnel roof. Photo by R. C. Zink, National Park Service.

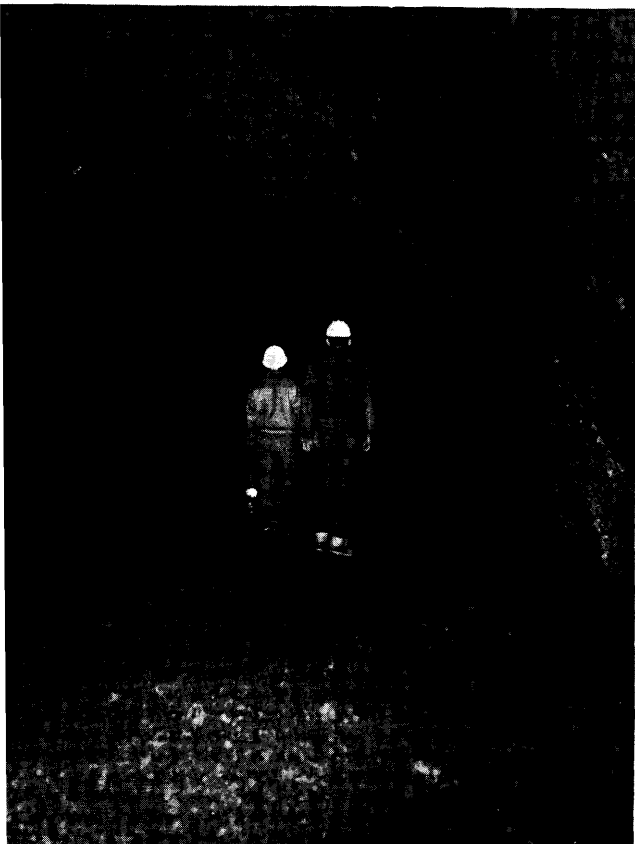


lava is not smooth and billowy but is rough, jagged, and spiny. It appears to owe its origin to a different combination of gas and heat. It has been established that an aa lava stream never changes into pahoehoe although in many cases pahoehoe flows change into aa. The cause for this change has not yet been determined definitely but field evidence indicates that there are differences in the amorphous glassiness, heat and gas content of the aa as compared with the pahoehoe. It is the escaping gas from the doughy mass which pulls out stringers of lava and causes the spines on the aa lava. It is usually difficult for the visitor to understand how such a great jumbled mass of lava clinkers ever could have flowed. The explanation is that the lava was in a pasty condition while in motion and floated this broken material along on its surface, continually furnishing more clinkers to the heap by granulation. Some of the fragments are pushed and rolled at the margin of

the flow, and others are dragged along under the lava. The whole flow resembles slush ice in a river in the spring of the year. The Monument contains aa lava flows 25 to 100 feet thick, some of which have moved several miles out on the plain.

TYPES OF CONES

Three different types of cones occur in the area — cinder cones, spatter cones, and lava cones. The cinder cones, with black, loose, cindery surfaces and smooth conical profiles, are familiar to everyone who has visited the Monument. These cones are heaps of the lava froth or spray formed by the fire-fountains that played at the time of the eruptions. Big Cinder Butte is the finest example in the area. The cinder cones, especially those in the northern part of the Monument, are elongated toward the northeast. They owe this unsymmetrical form to strong southwest winds that blew during the

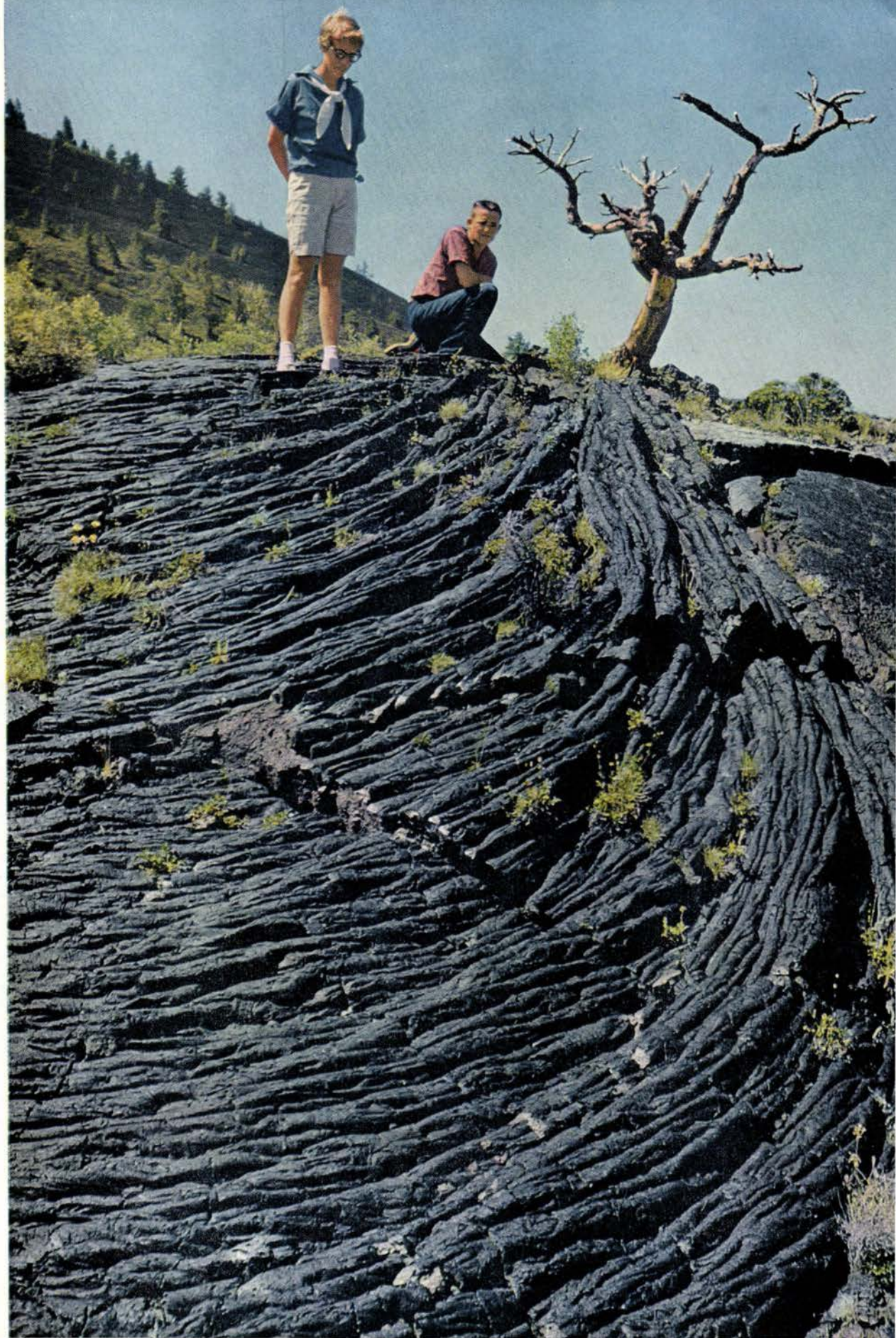


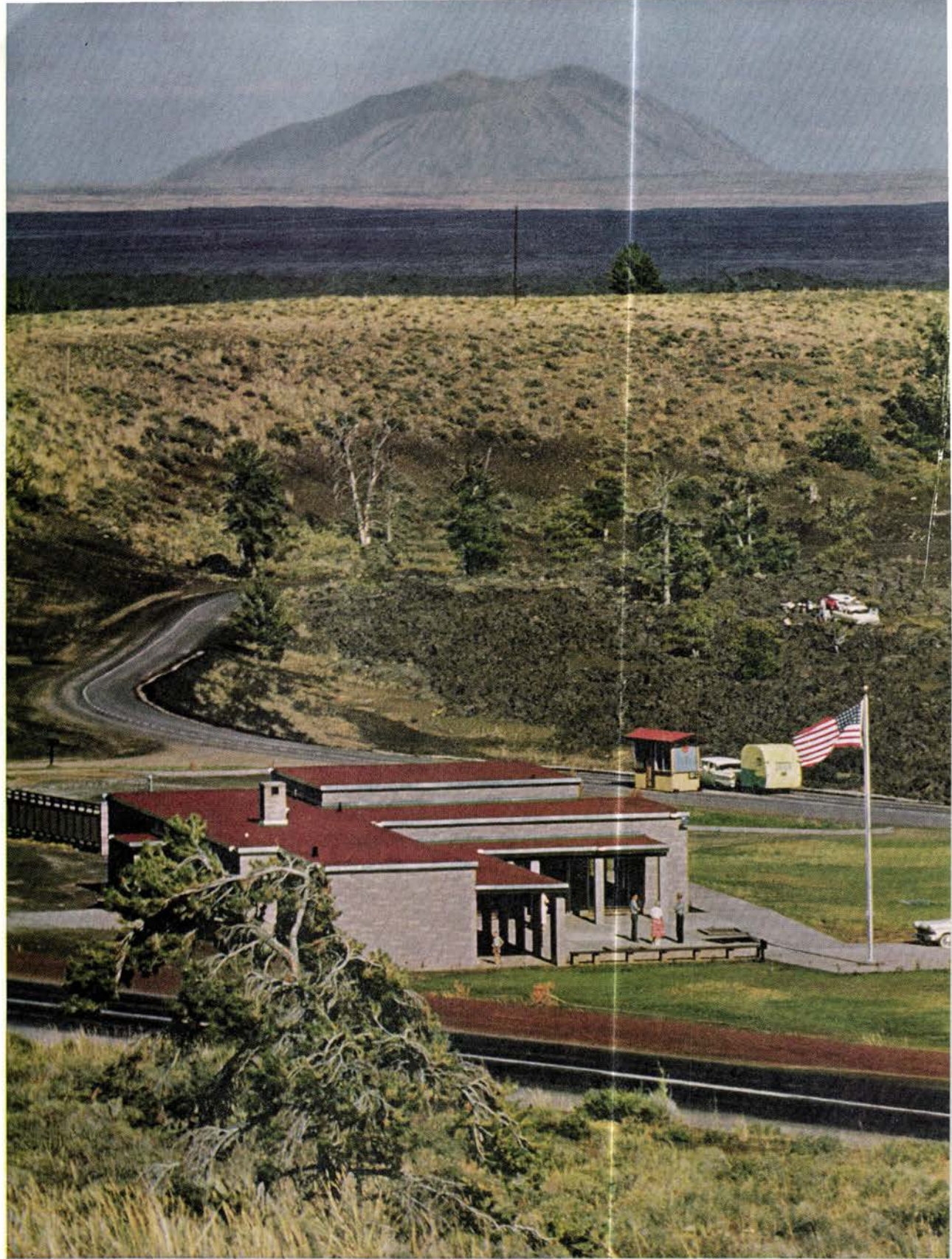
Exploring Arco tunnel, one of the many caverns in the Monument. Photo by D. C. Ochsner, National Park Service.

The ropy and wrinkled surface of the pahoehoe is due to the hardening of a thin crust or scum on the lava while the crust is being pushed forward by the flowing lava below. Photo by William Belknap, Jr.

Courtesy National Geographic Magazine © National Geographic Society

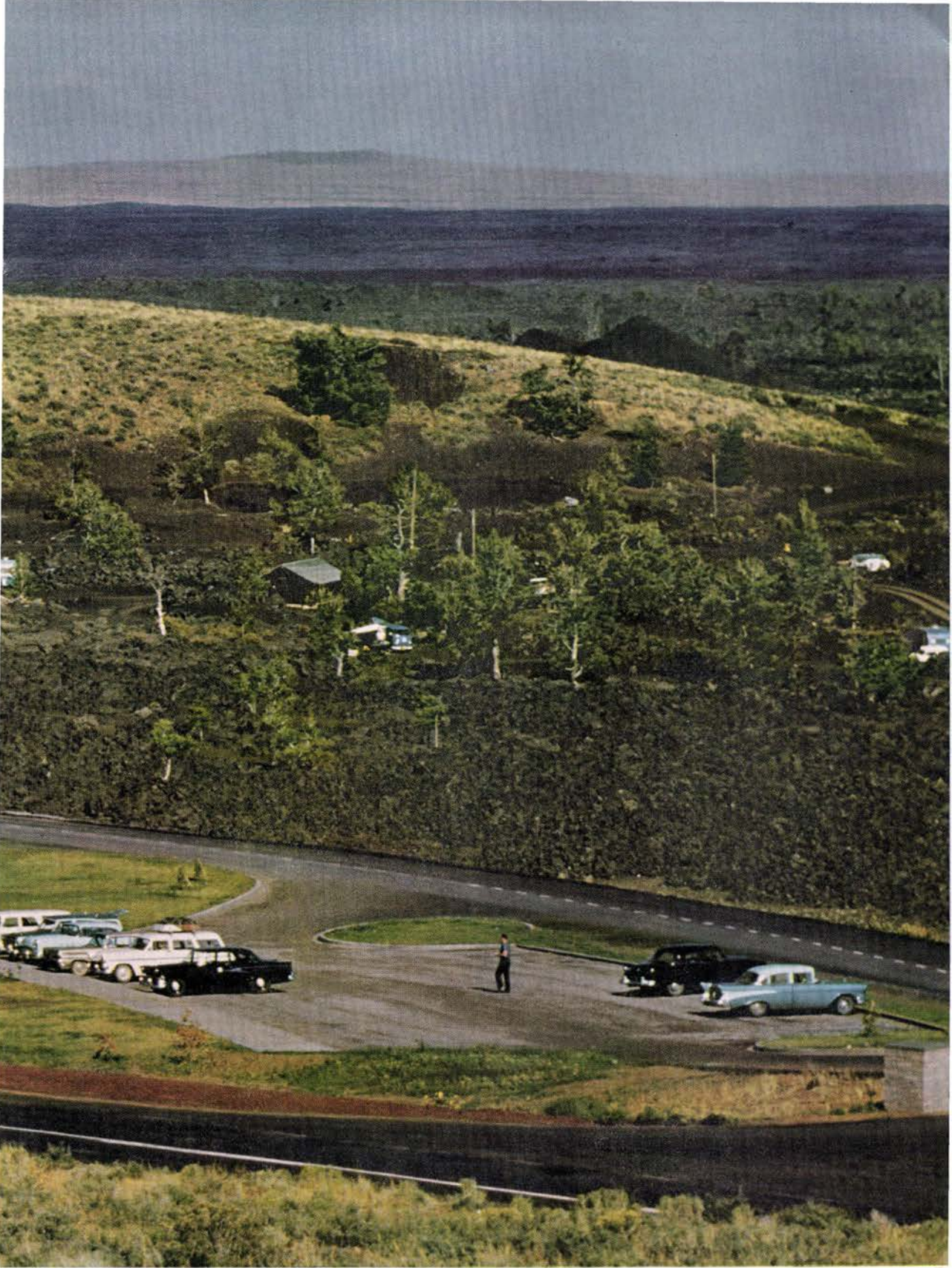






Big Southern Butte, 27 Miles Away, Looms Above the New Visitor Center
Sentinel of the Snake River Lava Plain, the

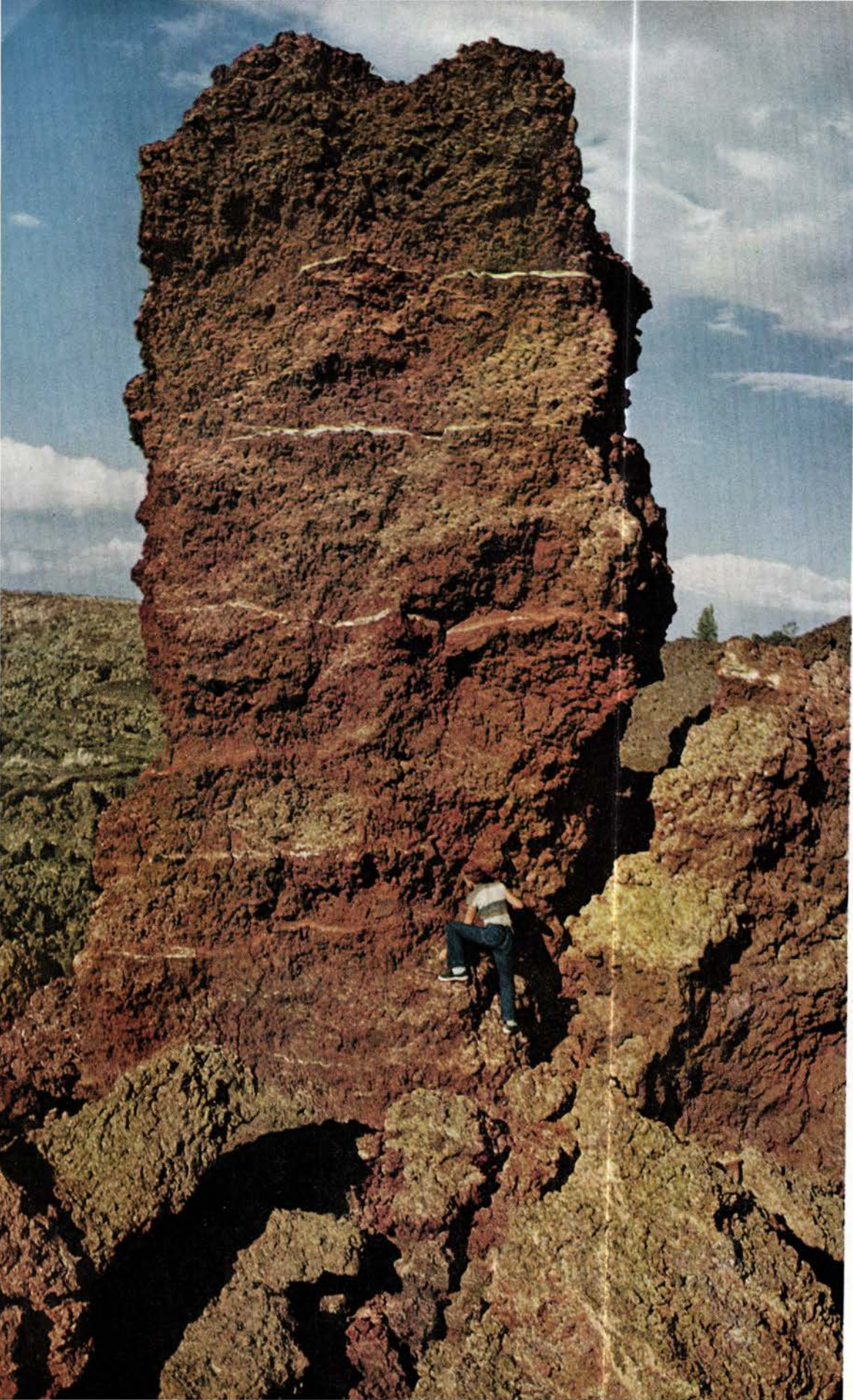
7,576-foot mountain served as a landmark to fur trappers and stagecoaches. It is the remnant of a very ancient silicious volcano that



antedates all the basaltic eruptions on the Snake River Plains. A campground laid amid brush and cinders stands across Loop Drive

from the headquarters building. Photo by William Belknap, Jr.

Courtesy National Geographic Magazine.



eruption, piling more of the cinders and lapilli on one side of the cones. Grassy Cone, North Crater Butte, and Silent Cone are all about 450 feet high. Grassy Cone is unlike its neighbors, however, in that it appears to have been formed during one great eruption. The length of time required to form this particular cone by a single eruption is of course unknown, but an interesting comparison of its size with that of a cone of the same type that has been formed elsewhere in historic time may throw some light on the subject. A little to the west of Pozzuoli, on the shore of the Bay of Naples, not far from the village of Baja, is a conical hill, composed of black cinders, which rises 440 feet above the adjacent waters of the bay. There is conclusive evidence that prior to 1538 the site of this cone was partly occupied by Lake Lucrine. The recent origin of the hill is indicated in its name, Monte Nuovo (new mountain). When visited by the writer in 1925 it supported a considerable growth of vegetation and resembled Grassy Cone in many respects. This cone covers an area of more than half a square mile and is comparable in volume to Grassy Cone. According to contemporary records based on testimony of eyewitnesses, the adjacent region was affected by earthquakes for more than two years, and on September 27 and 28, 1538, the shocks occurred with maximum frequency and intensity. Judd³ says:

About 8 o'clock on the morning of the 29th a depression of the ground was noticed on the site of the future hill, and from this depression water, which was at first cold and afterward tepid, began to issue. Four hours afterward the ground was seen to swell up and open, forming a gaping fissure, within which incandescent matter was visible. From this fissure numerous masses of stone, some of them "as large as an ox," with vast quantities of pumice and mud, were thrown up to a great height, and these falling upon the sides of

the vent formed a great mound. This violent ejection of materials continued for two days and nights, and on the third day a very considerable hill was seen to have been built up by the falling fragments, and this hill was climbed by some of the eye-witnesses of the eruption. The next day the ejections were resumed, and many persons who had ventured on the hill were injured and several killed by the falling stones. The later ejections were, however, of less violence than the earlier ones and seem to have died out on the seventh or eighth day after the beginning of the outburst. The great mass of this considerable hill would appear, according to the accounts which have been preserved, to have been built up by the materials which were ejected during two days and nights.

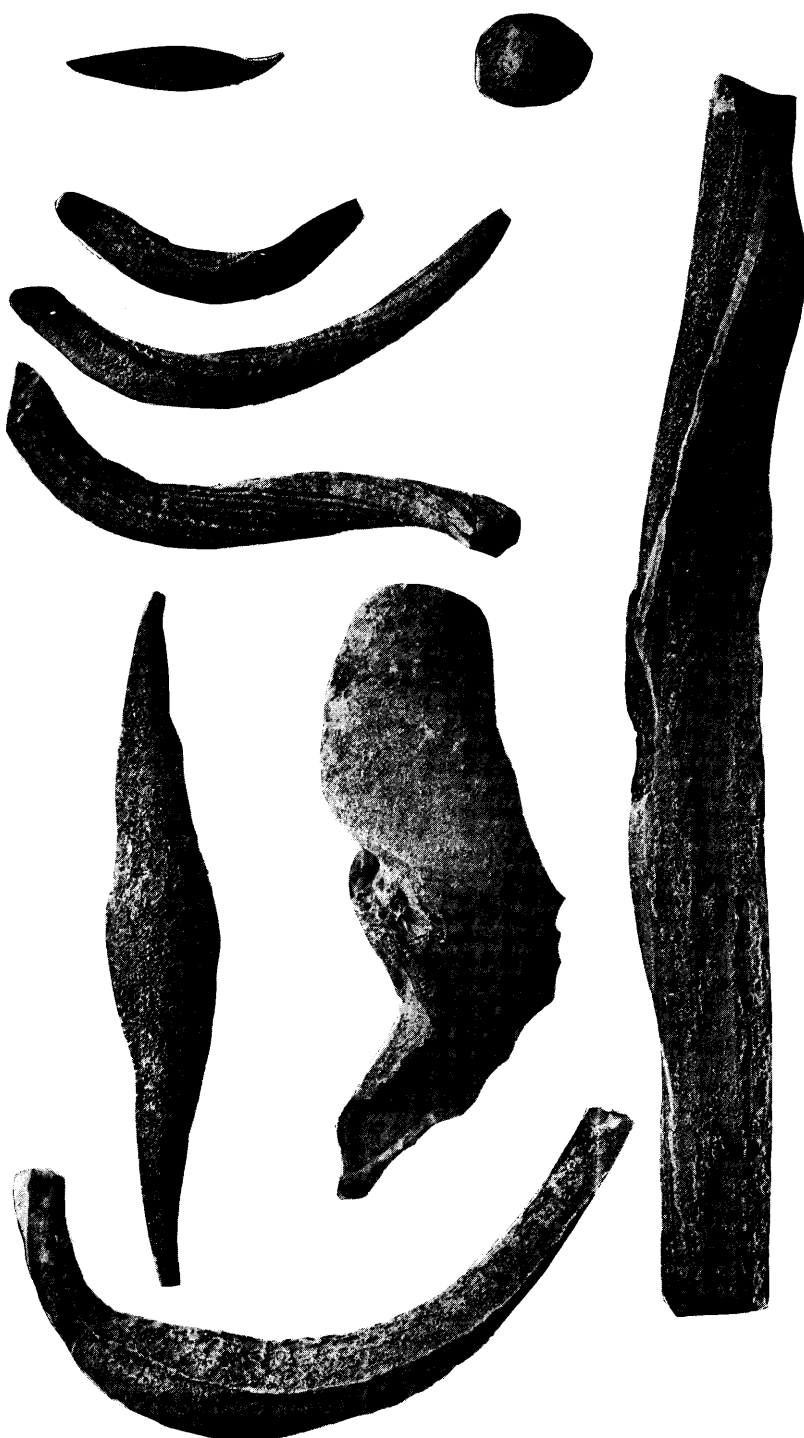
Spatter cones are formed by the smaller firefountains. The clots of lava hurled out by these fountains were not sufficiently inflated with gas to form cinders and moved so slowly and through distances so short that instead of landing as cold cinders they fell as clots in a viscous state and adhered to one another. They built up rather steep-sided cones of small height and diameter. Gypsum crystals and lava pendants adorn the interior of Crystal Cones. The crystals were deposited by exhalations after the eruption. The line of spatter cones near the end of the automobile road, all of which are less than 50 feet high and 100 feet in diameter, is one of the most perfect spatter-cone chains in the world.

The third type of cone found in the Craters of the Moon, but observed by very few visitors, is the lava cone, or, more properly, the lava dome. Some of these domes are surmounted by tiny spatter cones less than 10 feet high. Lava domes differ from spatter and cinder cones in that they consist of compact lava and have a broad, flat dome shape, many of them rising only 30 to 50 feet above the surrounding country. These inconspicuous domes are formed by the continuous quiet welling-out of pahoehoe lava on the surface from the same point. Because

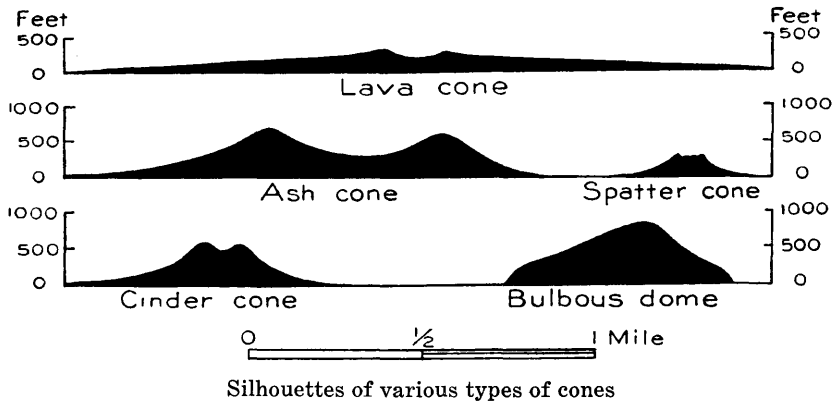


A cinder crag, portion of a cinder cone which floated away on a lava flow like a derelict ship. Photo by William Belknap, Jr.

Courtesy National Geographic Magazine © National Geographic Society



Some small spindle and ribbon bombs found on the cones in the Monument. Actual size.

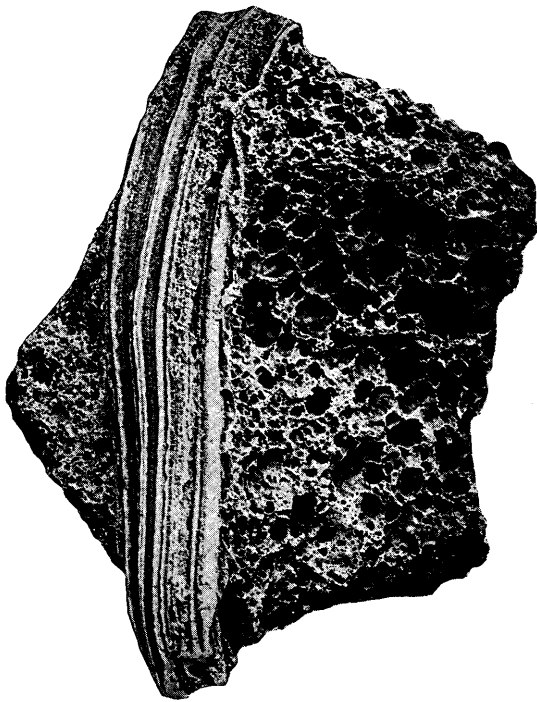


most of the lava escapes through tubes the cone is not built up very high. Great Owl Cavern, Indian Tunnel, and Needles Cave mark the sites of some of these lava domes. In size and shape and in the character of the lava extruded from it the Needles Cave dome closely resembles the dome of Mauna-iki, which was formed in 1920 on Kilauea Volcano, Hawaii. In the early part of December, 1919, numerous cracks opened on the southwest slope of Kilauea, and on December 21 lava welled out from one of the cracks. The stream of lava from this vent continued until July 28, 1920,⁴ and formed a flow 6 miles long and about half a mile wide. Part of the lava was pahoehoe, and part was aa. The fissure from which the lava issued was buried by the flow, and a lava dome 70 feet high and 1 mile across was developed over the fissure. On the summit of the dome is a small pit about 30 feet in diameter and 20 feet deep, due to the collapse that followed the eruption. This depression is smaller and less conspicuous than the one nearby formed by the collapse of the roof of the lava tube through which most of the lava escaped. If this eruption had not been witnessed no one would have surmised that the lava welled-out of a fissure about half a mile long. During this eruption lava escaped from four other fissures on the slope of Kilauea and formed small

isolated patches of lava and another small lava dome.⁵

BOMBS

Probably the most curious of all the lava features that are found in the Monument are the lava bombs that lie scattered on the cinder and spatter cones. These bombs range in length from half an inch to more than 13 feet and in diameter from a quarter of an inch to 3 feet. There are three classes of bombs — spindle bombs, ribbon bombs, and bread-crust bombs. Spindle bombs are those that have tapering projections on the ends of a football-shaped body. These bombs owe their origin to a clot of lava being hurled through the air with a rotational or spiral motion. Most of the best-formed bombs found by the writer were very close to their source, indicating that their flight was of short duration. Some of these bombs had long, tapering twisted ends that projected 3 to 10 inches from the main part. These long, thin strips of lava were broken off by the fall of the projectile and lie scattered on the surface. They are called ribbon bombs because of their shape. Some of the ribbon bombs owe their origin to the pulling apart of two clots of lava which traveled at slightly different speeds or in slightly different directions. The longer ribbon bombs, such as those 2 to 13 feet in length and



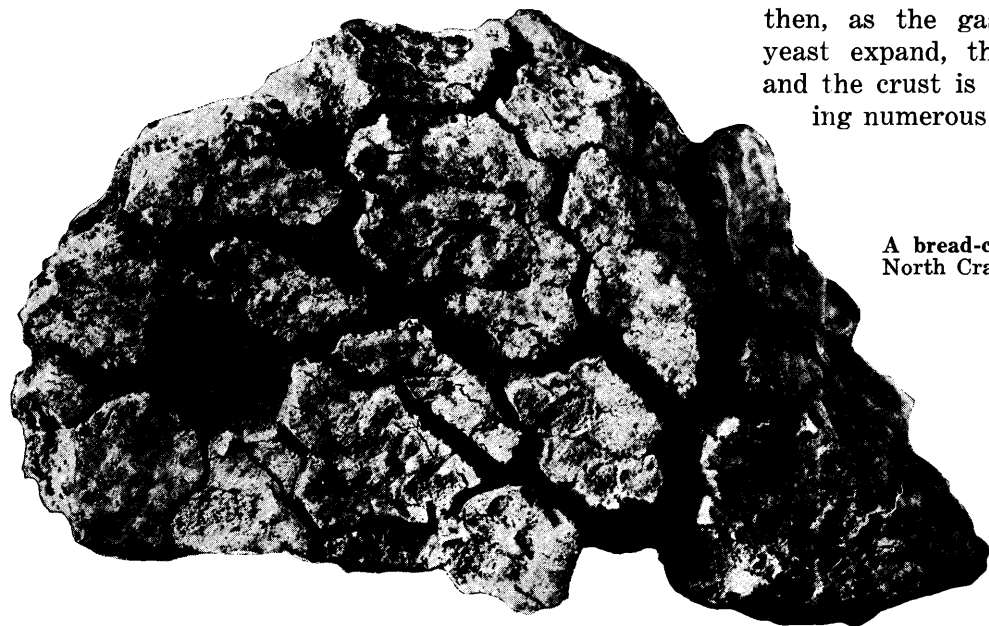
A ribbon bomb "frozen" to a cinder. Actual size.

only a few inches wide, seem to have originated in one of two different ways. A few of them are simply lava clots that landed on the side of a cone and ran down the slope while still plastic. Weathering and the removal of the cinders adjacent to some of these long lava trickles have caused them to become detached and to lie loose on the surface like bombs. Other ribbon bombs are formed by the throwing out from a spatter or cinder cone of a large clot of very liquid lava that stretches out during its flight and falls on cinders sufficiently loose to prevent its breaking into pieces.

Bombs of a third kind are light and porous and covered with a crust or skin that resembles the crust of bread. These are known as bread-crust bombs. They are formed by a clot of lava filled with gas being hurled through the air. During its flight a skin or crust forms on the clot, and as the bomb swells owing to the expansion of the included gases the skin is cracked open in many places, producing a number of small checks on the surface. In baking bread the same process can be observed.

First a thin crust bakes, and then, as the gases from the yeast expand, the loaf swells and the crust is broken, showing numerous small cracks.

A bread-crust bomb from North Crater. Actual size.



TREE MOLDS

Tree molds exist in certain lava flows in the Craters of the Moon where the lava flowed slowly and at the right temperature into a forest. When the charred or partly burned wood rotted away the hole formed a perfect mold of the part of the upright tree and the branches that were buried by the lava. The tree molds range in diameter from a few inches to 3 feet and are easily distinguished from other holes in the lava because they retain the form of the tree and its branches. Many of them are 10 to 20 feet deep, the depth depending upon the thickness of the lava that surrounded the tree and the amount of rock or cinders that has fallen or blown into the mold since it was formed. The explanation why molten lava does not completely obliterate a tree is due to the characteristics of lava flows. It is possible to walk on pahoehoe a short time after it crusts over and while there is still molten lava beneath, because a few inches of the lava crust cools rapidly and is sufficient to prevent any great amount of heat from escaping. Liquid lava at or near the temperature of solidification requires very little time to become a rock



The lava trees are tree molds that rise above the surface of the lava flow. This one, located on Trench Mortar Flat, is formed chiefly of spatter that was ejected from an adjacent fissure. Photo by H. T. Stearns.



The impressions of charred logs and the molds of the tree trunks are preserved in some places in the pahoehoe lava. Photo by H. T. Stearns.

that is a poor conductor of heat. Thus within a few minutes lava that surrounds a tree becomes a shell of solid rock. The burning started by the hot lava creates an air space or chamber between the tree and the mold which accelerates the cooling of the lava. The cooling process is further aided by the steam emitted from the sap of the tree. The writer saw trees in Hawaii with their upper portions uncharred and dead leaves still clinging to the branches over two years after their trunks had been partly buried by hot lava. There is much less chance for the formation of a mold from a dead tree, for it burns so rapidly that it may be destroyed completely while the lava is still plastic.

Most of the vertical tree molds do not preserve charcoal impressions, but in some places where the tops of the trees fell on the plastic lava the impression of the charred log and the delicate grain of the wood have been preserved. In places the lava was soft enough or was rendered plastic enough by the steam from the burning wood to flow into the checks or shrinkage cracks in the charred surface of the log, forming a pattern that is easily mistaken for bark impressions. Practically all the tree molds in the Monument were examined, but not one was found that showed bark impressions. The principal localities where tree molds have been found are given in the end tables.

There are two kinds of tree molds in the area. One kind, called lava trees,

is common on Trench Mortar Flat southeast of Big Craters Butte. These trees rise 1 to 5 feet above the lava surface. Lava trees are formed in the same manner as the tree molds just described but in localities favorable to the draining away of part of the lava flow, or they are due to trees being buried by spatter from a spatter vent. There are in Hawaii lava trees 40 feet high which consist of thin shells of lava surrounding charred remnants of trees. The other kind is represented by the tree molds of simple type that extend downward into the lava flow. The top of the tree is sometimes found molded near-by on the lava surface.

During the eruption of Etna in 1865 the lava entered a pine forest. The results of this invasion are described by Reclus⁶ as follows:

Sheaths of solidified lava were surrounding the trunks of pines, and thus showing the height to which the current of molten stone had reached.*** Below the escarpments of the Frumento, the torrent, which was there retarded in its progress, had not contented itself with bathing for a moment the trunks of the forest trees but had laid them low. Great trunks of trees, broken down by the lava, lay stretched in disorder on the uneven bed of the stream, and, although they were only separated from the molten matter by a crust a few inches thick, numbers of them were still clothed with their bark; several had even preserved their branches. At the edge of the cheire [aa lava] some pine trees, which had perhaps been preserved from the fire by their moisture being converted by heat into a kind of coating by steam, were surrounded by a wall of heaped-up lava, and their foliage still continued green; it could not yet be ascertained if the sources of the sap had perished in their roots. In some places rows of firs very close together were sufficient to change the direction of the flow and to cause a lateral deviation.

UNUSUAL OCCURRENCE OF WATER

The visitor to the Craters of the Moon on a hot July day is amazed at the ice-cold water found in the most unexpected places. The temperature of the water rarely exceeds 34° F. There are three kinds of places where water or ice is found. Most of the large water holes occur in depressions in very rough, broken lava. In these depressions, a considerable amount of snow collects in winter. Some of it sifts down into the crevices between the rocks and remains sheltered from the hot atmosphere during the long summer days. In addition, water during the thawing periods in the autumn or spring may drip downward into the crevices, where it is frozen by cold circulating air. During the long cold winters ice forms. Some of it melts in the summer, but in favored locations it never melts entirely away. Just as the solid lava is a poor conductor for the upward movement of heat from the molten lava beneath, so it is a poor conductor for the downward passage of heat from the sun. Usually a small amount of ice melts during the summer and forms a pool of water. If one digs

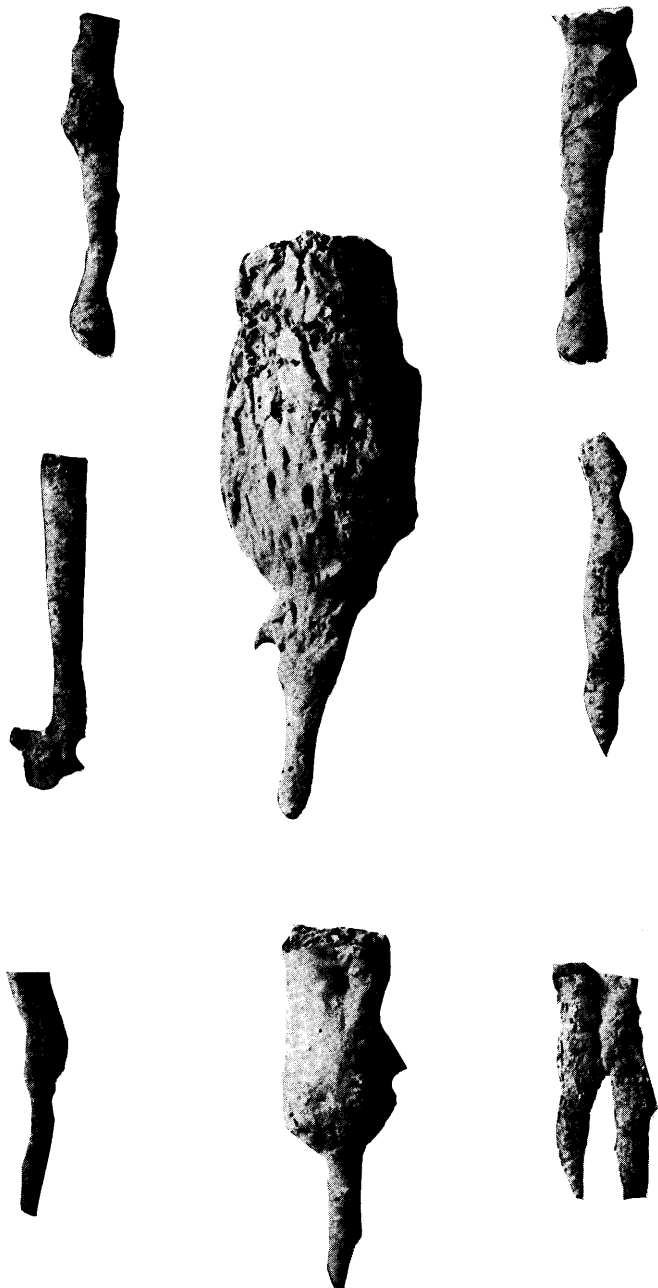
down into the loose rock in a water hole of this type, ice will always be found beneath the water.

Water and ice also occur in the lava caves or tubes where drafts of cold air freeze any water that percolates into them. The freezing period covers about seven months in the year, and during the remaining months there is a gradual wasting away of the ice. Even during the summer days the temperature of the interior of the caves does not rise above 40° F.; hence melting proceeds very slowly. Ice and water are also found in the deep inverted-funnel craters of the spatter cones. In occurrences of this type the snow accumulates in the crater during the winter and is exposed to the direct rays of the sun for only a short time each day. Thus, there results a continually increasing heap of ice. Snow Cone is of this type and contains a heap of snow and ice about 20 feet thick in its crater. The locations of the water holes are given in the end tables.

Many people imagine that some uncanny, mysterious method accounts for the formation of the ice, such as impossible chemical reactions and queer volcanic phenomena. On the active volcano of Kilauea, Hawaii, where

The narrow ledges parallel to the floor of Buffalo Caves mark temporary levels of a subsiding river of lava. Photo by D. C. Ochsner, National Park Service.

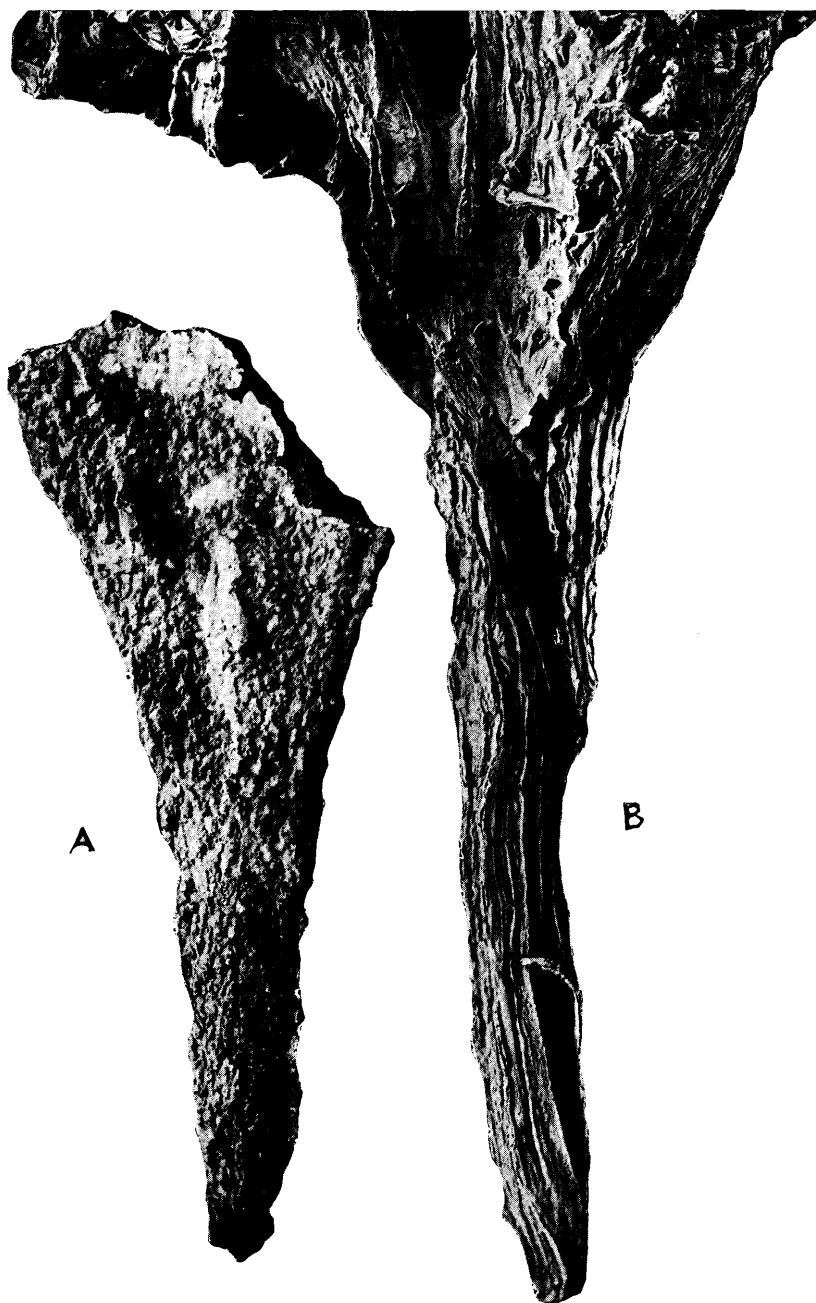




A few lava stalactites from the caves. They were formed by the dripping of the hot lava from the roofs of the tunnels. Actual size.

Bulbous stalactites in Arco tunnel formed by drip of lining as the lava level lowered in the tube. Photo by D. C. Ochsner, National Park Service.





A lava stalactite from the under surface of the crust of a pahoehoe lava flow (B), in contrast to a lava stalactite from the roof of a lava tunnel (A). Actual size.

thousands of similar caves occur and where immense quantities of rain fall, no ice occurs in the caves, but the explanation is apparent, for Kilauea has neither snow nor freezing temperature.

On the other hand, Mauna Loa volcano, which rises nearly 14,000 feet above the sea into the snow zone, contains numerous ice caves in and near the crater, and many of them are only

a stone's throw from a steam vent. Ice caves do not occur anywhere in the world except where there are freezing temperatures during some part of the year.

The lava in the Craters of the Moon is so extensively fissured that no water is found in it throughout the year except where the water is perched upon an impermeable body of ice and lava.

AGE OF THE FLOWS

Everyone who visits the Craters of the Moon is impressed with the freshness and barrenness of the black lava flows. However, the longer you remain and the more you see of the lava fields the more you will be impressed with the time that must have elapsed since the last eruption. The absence of soil on many of the flows is easily explained. All the fine dust that falls on the lava surface or results from the weathering of the crusts is blown off or sifts into adjacent cracks. This hidden soil accounts for the presence of the numerous shrubs and pines that have taken root in crevices where no soil is visible. In Hawaii many of the historic lava flows are covered with vegetation, but in the desert area on the southwest slope of Kilauea both historic and prehistoric lava flows appear equally fresh to the eye and are absolutely devoid of vegetation. In the Kau Desert the growing season is the full twelve months, and the plants growing in the area are adapted by age-long selection to growing on lava rocks.

In the Craters of the Moon the vegetation has a growing season of about four months. The writer found a limber pine that had been growing in the Big Craters lava—a flow which appears as black and recent as any other in the Monument. The pine took root in one of the cracks near the edge of

the flow, and it had favorable conditions for growth, because the roots found their way into the soil deposits beneath. The pahoehoe tongue of the Big Craters flow in which the tree grew is split open and wedged apart by the roots. This "age tree," as it may be called because it afforded a measurement of the minimum age of the lava, was $34\frac{1}{2}$ inches in diameter and was judged to have been dead only two or three years because of the pine needles still clinging to the branches. It was probably killed by lightning, as it showed a scar where a strip of bark about 4 inches wide was peeled off from top to bottom. It was perfectly sound and showed no burning scars nor any indications of fire. A count of the annular rings of this tree shows that it lived 461 years and hence was a good-sized tree before the discovery of America. Other larger trees rotting on the lava surface near-by may have been dead a hundred years. This lava was certainly extruded before these trees came into existence.

It is interesting to note Russell's impressions of the age of the flows in 1902. He states:⁷

No positive evidence was obtained to show that the dead trees which occur along their borders in certain instances were killed by the heat. The remnants of the craters from which the lava was poured out are tree clothed, and on the supposition that the lava outflows immediately followed the explosive eruptions which built the craters, the lava is older than the trees, many of which are fully 20 inches or 2 feet in diameter. 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 possibly 150 years.

Had Russell cut down one of these 20-inch pines that he saw growing on the cones in 1902 he would have been surprised at their great age, for limber pines with a diameter of 20 inches range in age from 250 to 300 years. Thus the basis of his estimate of the age of the lava flows is in error. The

writer found trees 24 to 30 inches in diameter lying on the surface of the cones. The advanced stage of decay of many of these trees indicates that they died possibly a hundred years ago. It must take considerable time for vegetation to start on a newly formed cinder cone in this semiarid region, in which only scattered growths of trees occur to provide the necessary seeds.

The charred trees on the cinder cones and at the edge of the flows which Russell mentions were carefully examined by the writer. They bear unmistakable evidence of having been burned by a brush fire set by lightning or by man. None of them was killed by the lava or by hot cinders. Several of the largest trees that grew at the edge of the lava with their trunks touching the rock are burned only on the side away from the lava, indicating that the fire spread through brush on the cinders. Some isolated charred trees standing on barren cinders were also burned by brush fires. The ashes of the brush disappeared, leaving barren stretches of cinders between the trees. Hence, it is not permissible to conclude, as some have done, that such trees were burned by the heat from the lavas.

Resting upon the Big Craters flow on which the "age tree" grew is the glistening pahoehoe from North Crater. Russell believed that this last flow from North Crater Cone was erupted immediately after the cone was formed but it appears from the degree of weathering that a considerable interval occurred between the formation of the cone and the outpouring of the glistening pahoehoe.

The "Triple Twist Tree" growing out of a crack in the North Crater Flow died in 1961 with a rotted heart. A core 16½ inches long removed from this tree by the Park Service in 1954 had 1350 years of growth as deter-

mined 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 lava flow may be several times this old.

EARLY EXPLORATION AND INDIAN HISTORY

In 1879 the late Mr. J. W. Powell, formerly of Arco, Idaho, visited this area. Having been offered a substantial reward for the discovery of sufficient water to supply several hundred head of cattle, Mr. Powell and Arthur Ferris explored in the early eighties the lava beds even beyond what is now the south boundary of the Monument. They were probably the first white men to visit the interior of this expanse of lava. A large stone marker built by Mr. Powell on this trip still stands near the water hole in Vermilion Chasm. A shoulder bone of a cow was found in 1926 in Buffalo Caves with the names of these two men and the date 1885 written on it. The writer visited Mr. Powell in 1926 and was surprised by his remarkable memory of the principal features in the area. Mr. Powell stated that in 1879 he interviewed Major Jim, a Bannock Indian scout, who spoke English well, regarding the time of the last eruption in the area. Major Jim replied that his great-great-great-grandfather saw fire in the region. On the basis of this statement the last eruption occurred in the early part of the eighteenth century. It is not impossible that an eruption occurred in the area at that time, but it is as likely that a fumarole or steam vent could have been considered fire by the Indian. That the Shoshone Indians



Hoodoo Water Hole,
in the serrate aa
lava flow, where
water only 1° or 2°
above the freezing
point can be found
on the hottest sum-
mer days. Photo by
H. T. Stearns.

frequented the area is shown by the fact that during the writer's investigation hunting blinds were found in the Little Prairie aa flow on the south side of The Watchman and several obsidian arrowheads, scrapers, and other artifacts were gathered. Mr. Era Martin found a nearly complete pottery bowl

near Echo Crater, and near Indian Tunnel are crescentic rock heaps. One theory is that these weighted down Indian tepees.

Several artificial mounds, now destroyed, existed at the north entrance to the Monument, in the cinders near the edge of the North Crater flow.



Margin of aa lava flow along the Great Owl Cavern trail in the Craters of the Moon National Monument. Photo by Peter G. Sanchez, National Park Service.

An aa lava flow crossing a road on Kilauea Volcano, Hawaii, May 21, 1955. Aa produces clinker by the forward motion of a very viscous lava which has lost most of its gases. Photo by G. A. MacDonald.





These mounds have been opened by several persons, but no human remains have been found in them. They consisted of cinders and sagebrush in alternate layers, and it is stated by one of the Indians living on the Fort Hall Reservation that mounds of this type were used to indicate trail directions. It is said that the sagebrush was laid lengthwise in the direction of the trail, which is now faintly discernible across the lava to the southeast.

Dim trails probably used by Indians and animals alike can be discerned here and there in the cinders or in the loose material on the surface of some of the lava flows. Three or four moss-covered pieces of lava rock or cinders piled on a prominent point may mark a trail or water hole, but the large conspicuous monuments have all been erected by white people. It is probable that the ancestors of the modern Indian witnessed eruptions in the area as Indians frequented the region for hunting or took refuge from enemies in the numerous caves and craters. However, to attempt to fix the date of an eruption on the basis of Indian tradition may lead to serious error. Everyone who has traveled among primitive tribes is aware of the amazing ability of such people to invent stories to explain everything to the satisfaction of the questioner. A good example of the imaginative character of some of the Indian legends is their story that a hard ledge of rock in Columbia River is the wreck of an ancient bridge built

by some of their ancestors. The Indians doubtless recognized from its appearance that the lava had once been molten and hot, and hence they may not have been slow in inventing a story regarding it.

FUTURE VOLCANIC ACTIVITY

So numerous have been the eruptions along the Great Rift that the rift might be likened to a great elongated volcano without a central orifice. It seems safe to predict that another eruption may occur in this area in the not too far distant future. The period covered by the history of our country is extremely short. Before 1914 Lassen Peak was cited in several books as an example of an extinct volcano in the United States, yet in 1914 and 1915 gigantic explosions occurred there. If these same explosions had occurred in a thickly settled part of our country they might have completely obliterated cities and killed thousands of people. Thus it is impossible to say whether a volcano is extinct or only dormant. It seems unlikely that on the Snake River Plateau, where thousands of volcanic outbursts have occurred during long ages and up to very recent time, all the volcanoes should have become extinct in the last moment of time. Instead, it appears that we happen to be living in a period of repose. The next eruption may come without any appreciable warning, although it is likely to be preceded by earthquakes.



The ice caves on a hot July day never cease to arouse the wonder and curiosity of the visitor. Icicles festoon the ceiling of Boy Scout Cave. Photo by William Belknap, Jr.

Courtesy National Geographic Magazine © National Geographic Society

APPROXIMATE ERUPTIVE SEQUENCE OF THE PRINCIPAL LAVA FLOWS IN THE AREA IN ORDER FROM YOUNGEST TO OLDEST

- | | |
|---|--|
| 1. Indian Tunnel flow | 14. Sheep Trail Butte flow |
| 2. Needles Cave flow | 15. Highway flow |
| 3. North Crater flow | 16. Coyote Butte flow |
| 4. Northeast Big Cinder Butte flow | 17. Trench Mortar Flat flow |
| 5. Southwest flow from Big Craters and Crystal Pit fissures | 18. Sentinel Butte flow |
| 6. Northwest Big Craters flow | 19. Fissure Butte flow |
| 7. Cave flow | 20. Ancient northeast flow from Big Cinder Butte |
| 8. Owl Cavern flow | 21. Vermilion Chasm flows |
| 9. Little Prairie aa flow | 22. Fissure flow northwest of The Sentinel |
| 10. Derelict flow | 23. Echo Crater flow |
| 11. Spatter-cone flow on Sheep Trail Butte | 24. Moss Cave flow |
| 12. Northeast Big Craters flow | 25. Grassy Cone flow |
| 13. Serrate flow | 26. Sunset Cone flow |
| | 27. Silent Cone flow |

PROMINENT CINDER CONES IN THE GREAT RIFT ZONE

NAME	Elevation above sea level.	Height above adjacent plain.	Section	Township	Range
	Feet	Feet			
Sunset Cone	6,386	590	26	2 N	24 E
Grassy Cone	6,351	450	34	2 N	24 E
North Crater Butte	6,338	440	35	2 N	24 E
Paisley Cone	6,050	350	1	1 N	24 E
Inferno Cone	6,177	300	1	1 N	24 E
Big Craters Butte	6,300	300	2	1 N	24 E
Silent Cone	6,346	450	2	1 N	24 E
Broken Top	6,060	225	12	1 N	24 E
Big Cinder Butte	6,516	800	13	1 N	24 E
Half Cone	6,041	350	18	1 N	25 E
Crescent Butte	6,089	490	11	1 N	25 E
Coyote Butte	5,907	300	19	1 N	25 E
Echo Crater Butte	5,850	250	29	1 N	25 E
The Watchman	5,871	325	28	1 N	25 E
The Sentinel	5,840	250	33	1 N	25 E
Split Butte	5,750	250	3	1 S	25 E
Fissure Butte	5,877	425	10	1 S	25 E
Sheep Trail Butte	5,617	150	10	1 S	25 E
Two Point Butte	5,471	120	23	1 S	25 E

OUTSIDE OF THE GREAT RIFT ZONE

Round Knoll	5,631	125	27	2 N	25 E
North Laidlow Butte	5,906	350	7	1 S	25 E
Bowl Crater Butte	5,596	50	18	1 S	25 E

LOCATION OF THE PRINCIPAL CAVES

NAME	Quarter		Section	Township	Range
Unnamed	SW $\frac{1}{4}$	SW $\frac{1}{4}$	12	1 N	24 E
Buffalo Caves	SE $\frac{1}{4}$	SE $\frac{1}{4}$	12	1 N	24 E
Great Owl Cavern	NE $\frac{1}{4}$	NE $\frac{1}{4}$	14	1 N	24 E
Lava River Cave	SW $\frac{1}{4}$	SW $\frac{1}{4}$	33	2 N	25 E
Last Chance Cave	NW $\frac{1}{4}$	SW $\frac{1}{4}$	4	1 N	25 E
Tom Thumb Tunnel	SE $\frac{1}{4}$	NE $\frac{1}{4}$	5	1 N	25 E
Horseshoe Cave	NE $\frac{1}{4}$	SE $\frac{1}{4}$	5	1 N	25 E
Needles Cave	NW $\frac{1}{4}$	SE $\frac{1}{4}$	5	1 N	25 E
Surprise Cave	NE $\frac{1}{4}$	SW $\frac{1}{4}$	6	1 N	25 E
Dewdrop Cave	NE $\frac{1}{4}$	SW $\frac{1}{4}$	6	1 N	25 E
Indian Tunnel	SE $\frac{1}{4}$	SW $\frac{1}{4}$	6	1 N	25 E
Unnamed	NW $\frac{1}{4}$	SW $\frac{1}{4}$	33	1 N	25 E
Moss Cave	SW $\frac{1}{4}$	NW $\frac{1}{4}$	36	1 N	25 E
Sunbear Cave	SW $\frac{1}{4}$	NW $\frac{1}{4}$	36	1 N	25 E
Amphitheater Cave	SW $\frac{1}{4}$	NW $\frac{1}{4}$	36	1 N	25 E
Unnamed	NW $\frac{1}{4}$	NW $\frac{1}{4}$	14	1 S	25 E
Unnamed	SW $\frac{1}{4}$	SW $\frac{1}{4}$	15	1 S	25 E

LOCATION AND SIZE OF THE PRINCIPAL NATURAL BRIDGES

NAME	Quarter	Section	Township	Range	Height	Span
Natural Bridge	SW	5	1 N	25 E	12	30
Indian Tunnel Bridge	SW	6	1 N	25 E	60	75
Bridge of Tears	NW	36	1 N	25 E	15	40
Bridge of the Moon	SE	16	1 S	25 E	20	60

LOCATION OF TREE MOLDS

Kind of mold	Name of lava flow	Section	Township	Range
Lava trees	Trench Mortar Flat	18	1 N	25 E
Lava trees	Tree Mold Flat	28, 29	1 N	25 E
Tree molds	Northwest flow from Big Craters	3	1 N	24 E
Tree molds	Owl Cavern flow	13	1 N	24 E
Tree molds	Blue Dragon flows	13	1 N	24 E
Tree molds	Blue Dragon flows	26	1 N	24 E
Tree molds	Blue Dragon flows	34	1 N	24 E
Tree molds	Black flows	15	1 N	25 E
Tree molds	Black flows	16	1 N	25 E

OCCURRENCES OF PERENNIAL WATER OR ICE¹

NAME	Quarter	Section	Township	Range
Registration Booth Water Hole ²	NW	1	1 N	24 E
Ice Cave	SE	2	1 N	24 E
Pit Crater Water Hole	NW	12	1 N	24 E
Big Sink Water Hole	NW	12	1 N	24 E
Owl Cavern	NE	14	1 N	24 E
Hoodoo Water Hole	SW	27	2 N	25 E
Surprise Water Hole	NE	29	2 N	25 E
Doves Water Hole	SW	30	2 N	25 E
Last Chance Cave	SW	4	1 N	25 E
Yellow Jacket Water Hole ³	SE	20	1 N	25 E
Bearsden Water Hole	NE	29	1 N	25 E
Little Prairie Water Hole	NE	29	1 N	25 E
Sheep Trail Butte Water Hole	SE	10	1 S	25 E
Ice Cave	SE	14	1 S	24 E
Ice Caves	NE	24	1 S	25 E

¹ Some have gone dry in recent years.

² Went dry for first time in 1928; near site of former registration booth.

³ Dry in September and October, 1926.

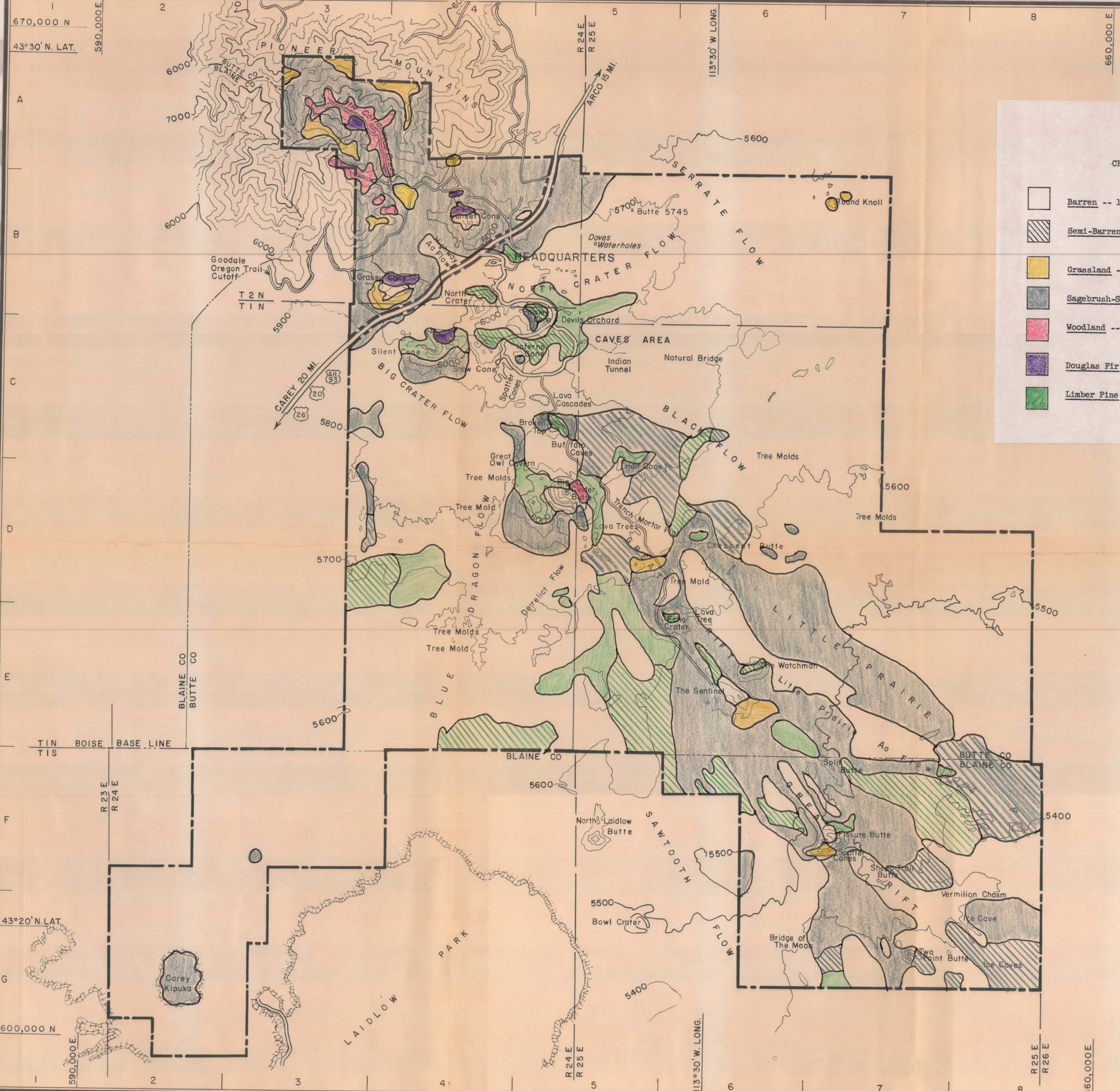
DEFINITIONS OF VOLCANIC TERMS

- Aa** — a lava flow with a rough clinkery or loose blocky surface. The rock contains deflated and stretched vesicles.
- Andesite** — a lava generally gray in color and richer in silicon and sodium and poorer in iron than basalt.
- Agglomerate** — a term sometimes used for aa lava or lumps of lava stuck together while still hot in a spattercone.
- Ash** — sand or dust size ejecta.
- Basalt** — a dark lava rich in iron and magnesium and comparatively poor in silicon; the common lava in the Monument.
- Blocks** — volcanic ejecta solid when thrown out and larger than 1½ inches across.
- Bombs** — volcanic ejecta molten when thrown out and having particular forms, such as ribbon, bread-crust, spindle, etc.
- Butte** — a hill rising abruptly above a plain.
- Cinder cone** — a mound built by small ejecta around a vent, with most of the fragments larger than ½ inch across, very vesicular, and mostly loose.
- Crater** — a depression at a volcanic vent.
- Dike** — the lava which solidified in a crack. Most are cross-jointed and with a long dimension much greater than the width. Basaltic dikes in the fissures of the Monument probably are less than 10 feet wide.
- Ejecta** — fragments of any size hurled out by a volcanic eruption.
- Fault** — a fracture in the earth's crust along which movement has occurred.
- Fault scarp** — a cliff formed by fault movement.
- Feldspar** — a light colored crystal with a complex silicate composition common in basalt.
- Fumerole** — a hole from which volcanic gases issue, usually lined with chemical deposits.
- Igneous rocks** — those formed by the solidification of magma.

Intrusive rock —	a rock which congealed in a fissure or other opening below ground.
Kipuka —	an island of old land surrounded but not covered by a lava flow. It can be higher or lower than the lava flow. Round Knoll is a kipuka.
Lapilli —	volcanic ejecta $\frac{1}{4}$ to about 1 inch across.
Lava —	either hot or solidified magma on the earth's surface.
Lava tree —	a tree mold which rises above the level of a lava flow.
Lithic —	stony.
Magma —	liquid lava beneath the surface.
Olivine —	a green crystal with a complex silicate composition common in basalts.
Obsidian —	volcanic glass formed by lava chilling too quickly to crystallize. Tachylyte is the technical name of basaltic glass.
Pahoehoe —	lava with a smooth or ropy surface spread chiefly through tubes and characterized by round vesicles.
Pumice —	frothy or highly vesicular ejecta, chiefly glass.
Pyroxene —	a dark colored crystal causing most of the dark color in basalt; it is a complex silicate.
Rhyolite —	a light colored lava rock, higher in silica and poorer in iron than a basalt.
Rift —	a lengthy fissure in the earth's crust.
Scoria —	slaggy vesicular ejecta.
Shield volcano —	a broad fairly flat lava cone having the shape of a shield. Commonly called "Lava Cone."
Solfatara —	a fumerole which gives vent chiefly to sulfurous gases.
Spatter cone —	a cone built by spatter around a vent. The clots stuck together when they fell.
Stalactite —	cylindrical and pointed pendants that hang from the roof of a cave. In the Monument they are composed of lava which dripped while viscous.
Stalagmite —	a small mound on the floor of a cave formed by the drip from a stalactite.
Tachylyte —	basaltic volcanic glass. See obsidian.
Tree mold —	a hole in a lava flow caused by lava making a cast of a tree trunk.
Tube —	a lava cavern through which pahoehoe lava flowed.
Vesicular —	having bubble holes formed by gas.
Vitric —	glassy.
Volcanic rift zone —	a zone of fissures from which lava has issued.

FOOTNOTES

- 1 IRVING, WASHINGTON, the Adventures of Captain Bonneville, U.S.A. Hudson ed., p. 203, New York, 1868.
- 2 For the reader interested in more detail regarding Hawaiian eruptions see Stearns, H. T. and Clark, W. O., Geology and ground-water resources of the Kau District, Hawaii including parts of the volcanoes of Kilauea and Mauna Loa Volcanoes: U.S. Geol. Survey Water Supply Paper 616, 194 pages, 1930 and Stearns, H. T. and MacDonald, G. A., Geology and ground-water resources of the Island of Hawaii: Hawaii Div. of Hydrography Bull. 9, 363 pages, 1946.
- 3 Judd, J. W., Volcanoes, pp. 76-77, New York, 1881.
- 4 Hawaiian Vol. Observatory Monthly Bull., vols. 7 and 8, 1919-20.
- 5 Stearns, H. T., and Clark, W. O., Geology and water resources of the Kau District, Hawaii: U.S. Geol. Survey Water-Supply Paper 616, 1930.
- 6 Reclus, Elisee, The Earth, vol. 2, p. 495, New York, G. P. Putnam & Sons, 1871.
- 7 Russell, I. C., Geology and water resources of the Snake River Plains of Idaho; U.S. Geol. Survey Bull. 199, p. 105, 1902.



RESOURCES MANAGEMENT PLAN
CRATERS OF THE MOON NATIONAL MONUMENT
APPENDIX C
Vegetative Cover Types

-  Barren -- less than 20% vegetated.
-  Semi-Barren -- Vegetation of any type covers less than 50% of ground surface.
-  Grassland -- Grass and grass-like species dominant.
-  Sagebrush-Shrub -- Sage and sage-like species dominant.
-  Woodland -- Aspen, Cottonwood or other broadleaved trees dominant.
-  Douglas Fir -- Douglas fir dominant species.
-  Limber Pine -- Limber pine dominant species.



No. 4 Older cones show sage-grass on south slopes, coniferous forest on north slopes. Foreground is younger cinder formation with pioneer cinder garden plants.



No. 5 Climax sage-grass community of Carey Kipuka. Subject of three completed research projects by SCS and others.



No. 6 SW view over flank eruption of the Watchman. White spots in center left show patches of pure grass communities.



No. 7 Aa flow and Sunset Cone in sage-grass community of NW Corner



No. 1 Much of the lava appears fresh and barren.



No. 2 A portion of Big Craters cinder cone complex.



No. 3 Aerial view SE from Sunset Cone vicinity. Silvery foreground is barren lava of North Crater Flow. Big Cinder Butte is in top center.

CRATERS OF THE MOON OF NORTHWEST PART IDAHO

Appendix D

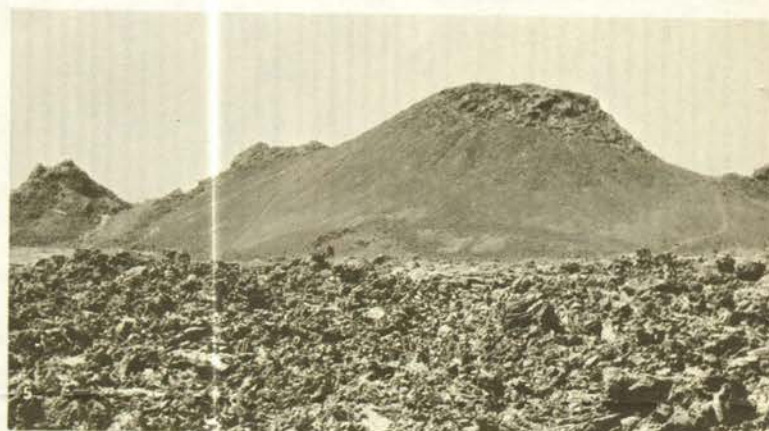
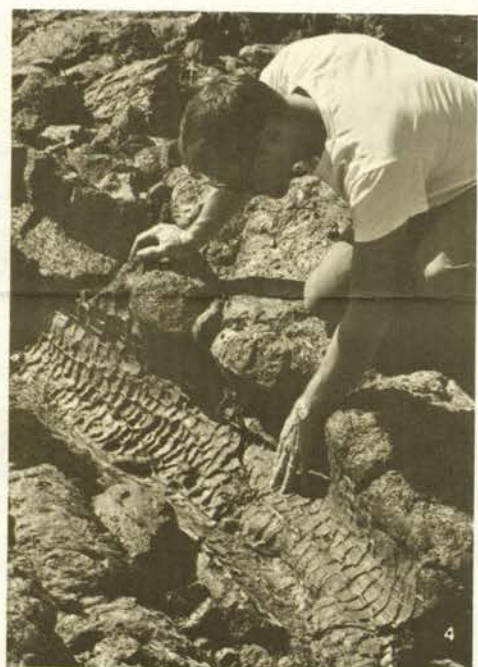
Dwarf Mistletoe Control Zones

1962 to ?





"Bombs," or ejected lava blobs.



1 Naturalist trips are conducted in summer. 2 Some lava wrinkled as it flowed. 3 Eroded remnants of crater walls. 4 Outline of a tree enveloped by lava. 5 Fragmented lava dominates this approach to Big Craters. 6 An explorer examines the prickly ceiling of a lava tube.



OTHER PLACES OF INTEREST

You may want to walk one of the several trails that range from a 20-minute walk in Devils Orchard to a 2-hour hike to Great Owl Cavern and the tree mold area. Or if you are a veteran explorer, a vast lava wilderness lies waiting in the southern end of the monument. Be sure to check with a ranger for suggestions on this trip.

The Devils Orchard Nature Trail is a delightful 1/3-mile walk through a weird array of cinder fields and crater-wall fragments. A folder, available at the trailhead and the visitor center, tells the story of animal and plant communities. Some of the small mammals to look for along the trailside are the yellow-pine chipmunk, golden-mantled ground squirrel, red squirrel (chickaree), and yellow-bellied marmot. Other animals less frequently seen are the mule deer (look for his trails), coyote, and bobcat. In early morning or late afternoon, listen for the songs of the rock wren, Clark's nutcracker, and mourning dove. The brilliant mountain bluebird and acrobatic violet-green swallow frequent the area during midday.

Boy Scout Cave has a floor of ice, even in summer. This natural icebox was formed when melting snow and rain seeped into the cave and was cooled to a subfreezing temperature by the long winters. Entrance to these smaller caves is difficult and a lantern is necessary.

NATURALIST ACTIVITIES

A 1-hour auto caravan is scheduled several times daily in summer. Stops are made at points of interest while the naturalist explains the story of volcanism. This is also an excellent opportunity to learn about the colorful wildflowers.

Each evening during summer, an illustrated program is given at the campground on geology, plants, or wildlife of the monument. A shorter program is scheduled in the visitor center at regular intervals during the day.

HUMAN HISTORY

An ancient Indian trail followed the Great Rift, while caves along the route were used as temporary shelters and probably, at times, as strongholds. At Indian Tunnel the semicircular

The 7-mile loop road is normally throughout the year, though heavy snow temporarily close it in winter.

Gasoline, food, and souvenirs are NOT able in the monument.

PRESERVATION OF THE MONUMENT

Regulations have been designed to protect the natural condition of the monument, at your safety and convenience.

Please do not damage the volcanic features or disturb flowers, trees, and rocks, or the wildlife. Use of firearms is not permitted.

Drive only on established roads and trails. Camp and picnic in the established campground. **HELP KEEP THE MONUMENT CLEAN.**

Pets are allowed, provided you keep them under physical restraint at all times.

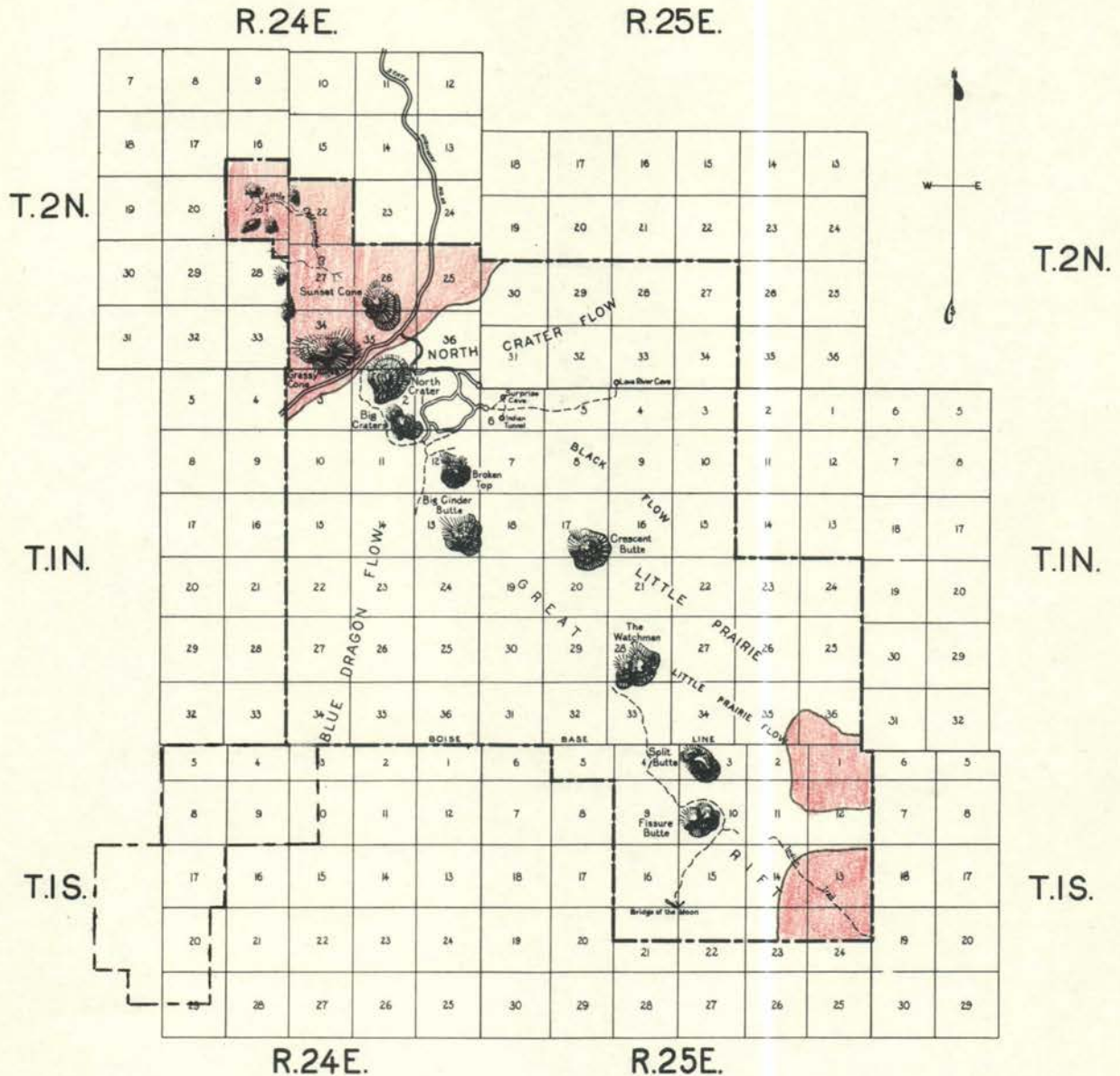
ADMINISTRATION

Craters of the Moon National Monument, established on May 2, 1924, is administered by the National Park Service, U.S. Department of the Interior.

The National Park System, of which this

CRATERS OF THE MOON NATIONAL MONUMENT IDAHO

APPENDIX E. FIRE CONTROL ZONES



LEGEND

- All fires will be suppressed.
- Zone where permissive burning will be applied when conditions permit.

DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary
NATIONAL PARK SERVICE
Arno B. Cammerer, Director
PREPARED BY
BRANCH OF PLANNING
Drawn By R.E.C. Drawing N° NMCM 7000

Corrected 6/12/36.

7/2/37

Checklist of PlantsCraters of the Moon National MonumentCommon names - alphabetical

Agoseris, slender	<u>Agoseris gracilens</u>
Alumroot, ovalleaf	<u>Heuchera ovalifolia</u>
Arnica, heartleaf	<u>Arnica cordifolia</u>
Aster, hoary	<u>Aster canescens</u>
Avens, largeleaf	<u>Geum macrophyllum</u>
Balsamroot, arrowleaf	<u>Balsamorhiza sagittata</u>
Bedstraw, shrubby	<u>Galium multiflorum</u>
Bedstraw, northern	<u>G. Watsoni</u>
Bedstraw	<u>G. boreale</u>
Bitterbrush, antelope	<u>Purshia tridentata</u>
Bitterroot, lewisia	<u>Lewisia rediviva</u>
Blazingstar	<u>Mentzelia dispersa</u>
Brickellia, tasselflower	<u>Brickellia grandiflora</u>
Ceanothus, snowbrush	<u>Ceanothus velutinus</u>
Chaenactis, Douglas	<u>Chaenactis douglasii</u>
Chokecherry, common	<u>Prunus virginiana</u>
Chokecherry, black	<u>Prunus virginiana melanocarpa</u>
Cinquefoil	<u>Potentilla arguta</u>
Cinquefoil, biennial	<u>P. bienis</u>
Cinquefoil, gland	<u>P. glandulosa</u>
Cinquefoil, Alberta	<u>P. pseudorupestris</u>
Columbine, sitka	<u>Aquilegia formosa</u>
Cowparsnip, common	<u>Heracleum lanatum</u>
Cryptantha	<u>Cryptantha Torreyana</u>
Cryptantha	<u>C. spiculifera</u>
Currant, golden	<u>Ribes, aureum</u>
Currant, wax	<u>R. cereum</u>
Currant, squaw	<u>R. inebrians</u>
Deathcamas, meadow	<u>Zigadenus venenosus</u>
Dogwood, redosier	<u>Cornus stolonifera</u>
Dwarfmistletoe	<u>Arceuthobium campylopodum</u>
Eriogonum, broom	<u>Eriogonum vimineum</u>
Eriogonum, cushion	<u>E. ovalifolium</u>
Eriogonum, slenderbush	<u>E. microthecum</u>
Eriogonum, sulphur	<u>E. umbellatum</u>
Eriogonum, wyeth	<u>E. heracleoides</u>
Erysimum, coast	<u>Erysimum capitatum</u>
Eriophyllum, woolly	<u>Eriophyllum lanatum</u>
Eupatorium, western	<u>Eupatorium occidentale</u>
Eveningprimrose, tufted	<u>Oenothera caespitosa</u>
Ferns	
Brittle bladderfern	<u>Cystopteris fragilis</u>
Oregon woodsia	<u>Woodsia oregana</u>
Eaton hollyfern	<u>Polystichum scopulinum</u>

Fireweed	<u>Epilobium angustifolium</u>
Fleabane, fernleaf	<u>Erigeron compositus</u>
Fleabane, Eaton	<u>E. eatoni</u>
Fleabane, Oregon	<u>E. speciosus</u>
Fleabane, aspen	<u>E. macranthus</u>
Fleabane, Low	<u>E. pumilis</u>
Fleabane, dwarf	<u>E. nanus</u>
Fritillary, purplespot	<u>Fritillaria atropurpurea</u>
Geranium	<u>Geranium nervosum</u>
Giant hyssop, nettleleaf	<u>Agastache urticifolia</u>
Gilia, skyrocket	<u>Gilia aggregata</u>
Gilia, Brewer	<u>G. breweri</u>
Gilia, slenderleaf	<u>G. linearis</u>
Globemallow, Munro	<u>Sphaeralcea nummosea</u>
Globemallow, stream	<u>S. rivularis</u>
Goldaster, hairy	<u>Chrysopsis villosa</u>
Goldenweed, dwarf	<u>Aplopappus nanus</u>
Grasses	
Annual hairgrass	<u>Deschampsia danthonioides</u>
Beardless bluebunch wheatgrass	<u>Agropyron inerme</u>
Bloomers ricegrass	<u>Oryzopsis bloomeri</u>
Bottlebrush squirreltail	<u>Sitanion hystrix</u>
Cheatgrass brome	<u>Bromus tectorum</u>
Fire reedgrass	<u>Calamagrostis koelerioides</u>
Giant wildrye	<u>Elymus condensatus</u>
Indian ricegrass	<u>Oryzopsis hymenoides</u>
Mountain brome	<u>Bromus carinatus</u>
Needle and thread	<u>Stipa comata</u>
Reed canarygrass	<u>Phalaris arundinaceae</u>
Sandberg bluegrass	<u>Poa secunda</u>
Slender wheatgrass	<u>Agropyron pauciflorum</u>
Slender hairgrass	<u>Deschampsia elongata</u>
Western needlegrass	<u>Stipa occidentalis</u>
Gromwell, wayside	<u>Lithospermum rudemale</u>
Groundsmoke	<u>Gayophytum Helleri</u>
Groundsmoke	<u>G. ramosissimum</u>
Groundsmoke	<u>G. racemosum</u>
Groundsel, woolly	<u>Senecia canus</u>
Groundsel, butterweed	<u>S. serra</u>
Hawksbeard, tapertip	<u>Crepis acuminata</u>
Helianthella, oneflower	<u>Helianthella uniflora</u>
Hopsage, spiny	<u>Grayia spinosa</u>
Knotweed, Douglas	<u>Polygonum douglasii</u>
Larkspur, Menzies	<u>Delphinium Menziesii</u>
Larkspur, Nuttall	<u>D. nuttallianum</u>
Larkspur, Anderson	<u>D. andersoni</u>
Larkspur	<u>D. glaucescens</u>
Lewisia, bitterroot	<u>Lewisia rediviva</u>
Lupine, tailcup	<u>Lupinus caudatus</u>
Lupine, velvet	<u>L. leucophyllus</u>

Mallow, maple
 Maple, Rocky Mountain
 Mariposa, sagebrush
 Mariposa, broadfruit
 Meadowrue, western
 Mentzelia, blazingstar
 Milkvetch, Canada
 Mockorange, Lewis
 Monkeyflower, common
 Monkeyflower, Lewis
 Monkeyflower, dwarf

Nettle, Lyall

Onion, wild

Paintedcup, northwestern
 Paintedcup, scarlet
 Parsley, desert
 Parsnip, wild
 Penstemon, scabland
 Penstemon
 Penstemon
 Phacelia, varileaf
 Phacelia, silverleaf
 Phlox, longleaf
 Phoenicaulis, wallflower
 Pricklepear, plains
 Pricklepear

Rabbitbrush, rubber
 Rabbitbrush, Douglas
 Rockcress, Holboell
 Rockspirea, creambush
 Rockspirea
 Rose, woods
 Russianthistle, tumbling

Sagebrush, big
 Sagebrush, Louisiana
 Serviceberry, saskatoon
 Serviceberry, Utah
 Silene, Menzies
 Skeletonplant, thorn
 Snowbrush, ceanothus
 Snowberry, whortleleaf
 Snowberry, Utah
 Solomonplum, feather
 Solomonplum, starry
 Speedwell, American
 Stickseed
 Sunflower, common

Iliamna rivularis
Acer glabrum
Calochortus macrocarpus
C. nitidus
Thalictrum occidentale
Mentzelia laevicaulis
Astragalus canadensis
Philadelphus lewisi
Mimulus guttatus
M. lewisi
Mimulus nanus

Urtica lyalli

Allium sp.

Castilleja angustifolia
C. miniata
Pteryxia terebinthina
Cymopterus sp.
Penstemon deustus
P. cyaneus
P. subglaber
Phacelia heterophylla
P. leucophylla
Phlox longifolia
Phoenicaulis cheiranthoides
Opuntia polyacantha
O. rhodantha

Chrysothamnus nauseosus
C. viscidiflorus
Arabis holboellii
Holodiscus discolor
H. microphyllus
Rosa woodsii
Salsola Kali tenuifolia

Artemisia tridentata
A. ludoviciana
Amelanchier alnifolia
Amelanchier utahensis
Silene menziesii
Lygodesmia spinosa
Ceanothus velutinus
Symphoricarpos vaccinoïdes
S. utahensis
Smilacina racemosa
S. stellata
Veronica americana
Hackelia floribunda
Helianthus annuus

Tansybush
 Thistle, Russian tumbling
 Thistle
 Tobacco, coyote
Trees

Black cottonwood
 Douglas-fir
 Limber pine
 Quaking aspen
 Rocky Mountain maple
 Sierra juniper
 Thinleaf alder

Violet, Beckwith

Wallflower phoenicaulis
 Waterleaf, baldhead
 Willow, scouler
 Willowweed, Sierra
 Wirelettuce

Yarrow, western

Chamaebatiaria millefolium
Salsola Kali tenuifolia
Cirsium sp.
Nicotiana attenuata

Populus trichocarpa
Pseudotsuga taxifolia
Pinus flexilis
Populus tremuloides
Acer glabrum
Juniperus occidentalis
Alnus tenuifolia

Viola beckwithi

Phoenicaulis cheiranthoides
Hydrophyllum capitatum
Salix scouleriana
Epilobium brevistylum
Stephanomeria tenuifolia myrioclada

Achillea lanulosa

Checklist of MammalsCraters of the Moon National MonumentScientific NamesChiropteraCorynorhinus rafinesquii pallescens

western big-eared bat

LagomorphaOchotona princeps

pika

Lepus townsendii townsendii

whitetail jackrabbit

Lepus americanus bairdii

snowshoe hare

Lepus californicus deserticola

blacktail jackrabbit

Sylvilagus nuttallii grangeri

mountain cottontail

Sylvilagus idahoensis

pygmy rabbit

RodentiaMarmota flaviventris

yellowbelly marmot

Citellus columbianus columbianus

columbian ground squirrel

Citellus lateralis tescorum

golden-mantled squirrel

Eutamias minimus pictus

least chipmunk

Eutamias amoenus

yellowpine chipmunk

Tamiasciurus hudsonicus richardsoni

red squirrel

Thomomys talpoides

northern pocket gopher

Perognathus parvus

great basin pocket mouse

Castor canadensis

beaver

Peromyscus maniculatus sonoriensis

deer mouse

Neotoma cinerea

bushytail wood rat

Microtus montanos

mountain vole

Microtus longicaudus

longtail vole

Zapus princeps

western jumping mouse

Erethizon dorsatum

porcupine

CarnivoraCanis latrans lestes

coyote

Vulpes fulva macroura

red fox

Mustela frenata

longtail weasel

Taxidea taxus neglecta

badger

Spilogale gracilis saxatilis

spotted skunk

Lynx rufus pallescens

bobcat

ArtiodactylaOdocoileus hemionus hemionus

mule deer

Antilocarpa americana americana

pronghorn

HypotheticalSorex merriami Merriam shrew Sorex vagrans vagrant shrewSorex palustris northern water shrewCitellus townsendii Townsend ground squirrelGlaucomys sabrinus Northern flying squirrelDipodomys ordii Ord kangaroo ratReithrodontomys megalotis western harvest mousePeromyscus crinitus canyon mouseOnychomys leucogaster northern grasshopper mouseLagurus curtatus sagebrush vole

APPENDIX H

Checklist of Birds Craters of the Moon National Monument January 24, 1966

COMMON NAMES

Vulture, turkey

Hawks & Eagles

- Red-tailed hawk
- Swainson's hawk
- Rough-legged, American
- Rough-legged, Ferruginous
- Marsh hawk
- Golden eagle
- Bald eagle
- Sparrow hawk
- Pigeon hawk

Grouse & Partridges

- Blue grouse
- Sage grouse
- Chukar
- Gray partridge
- Ring-necked pheasant

Pigeons & Doves

- Rock dove
- Mourning dove

Owls

- Great horned owl
- Long-eared owl
- Saw-whet owl
- Screech owl
- Short-eared owl

Goatsuckers

- Nighthawk, common

Hummingbird, broadtailed

Woodpeckers

- Red-shafted flicker
- Lewis woodpecker
- Downy woodpecker
- Hairy woodpecker
- Yellow-bellied sapsucker

Flycatchers

- Western kingbird
- Western wood pewee
- Say's phoebe

Larks

- Horned lark

Swallows

- Violet green swallow
- Barn swallow

Jays, Magpies & Crows

- Gray jay
- Steller's jay
- Pinon jay
- Common raven
- Common crow
- Clark's nutcracker
- Magpie, black-billed

Titmice, etc.

- Chickadee, mountain

Nuthatches & Creepers

- White-breasted nuthatch
- Red-breasted nuthatch
- Brown creeper

Wren, rock

Mockingbirds & Thrashers

- Sage thrasher
- Catbird

Thrushes, Bluebirds, Solitaires

- Robin
- Varied thrush
- Mountain bluebird

Waxwing, Bohemian

- Shrike, northern

Starling

Wood warblers

- Augubon's warbler
- Orange-crowned warbler
- Yellow warbler

Meadowlarks, Blackbirds & Orioles

- Western meadowlark
- Yellow-headed blackbird
- Redwinged blackbird
- Brewer's blackbird
- Bullock's oriole
- Cowbird, brownheaded

Tanager, western

Grosbeaks, Finches, Sparrows & Buntings

- Lazuli bunting
- Snow bunting
- Evening grosbeak
- Pine grosbeak
- House finch
- Black rosy finch
- Gray-crowned rosy finch
- Cassin's finch
- Pine siskin
- American goldfinch
- Green-tailed towhee
- Rufous-sided towhee
- Vesper sparrow
- Lark sparrow
- Sage sparrow
- Song sparrow
- Chipping sparrow
- Brewer's sparrow
- White-throated sparrow
- Oregon junco

APPENDIX I

Checklist of ReptilesCraters of the Moon National Monument

Western toad	<u>Bufo boreas</u>
Western skink	<u>Eumeces skiltonianus</u>
Short-horned lizard	<u>Phrynosoma douglassi</u>
Rubber boa	<u>Charina bottae</u>
Great Basin rattlesnake	<u>Crotalus viridis</u> <u>lutosus</u>
Western yellow-bellied racer	<u>Coluber constrictor</u> <u>mormon</u>
Gopher snake	<u>Pituophis catenifer</u>