NORRIS GEYSER BASIN

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FOREWORD

Since my first summer in Yellowstone the Norris area and particularly the Geyser Basin has held fast to a spot high on my list of favorite places. The writing of this account has afforded me a great deal of personal satisfaction, and it is my sincere hope that every reader may experience a great deal of the same as a result of his association with it. I am sure it will have served a useful purpose indeed if it inspires readers to go into the area to observe and enjoy it first hand. I can predict with complete assurance that no person who does so will be disappointed.

The Norris Geyser Basin displays no geysers comparable in size to the major ones found in the Lower and Upper geyser basins along the Firehole River, but people who know it well and those who take time to appreciate the great variety of thermal features found here consider it to be one of the most interesting and appealing thermal areas in Yellowstone National Park. In this basin are representatives of every type of thermal feature; minute fumaroles no larger than pipe stems emitting blistering hot gases and depositing beautiful sulfur crystals, geysers erupting upwards of 50 feet, beautifully colored quietly ebullating hot pools, superheated steam vents roaring with demoniac fury, sizzling "frying pan" springs and bubbling caldrons of different colored muds. All these and many more related types of hydrothermal vents have intrigued visitors to the Norris Geyser Basin since its discovery in 1872, and although no geyser found there has attained Old Faithful's stature and the area is thus by

comparison unknown, it is hoped this publication may help establish the Norris Geyser Basin in its rightful high place on the long list of Yellowstone wonders.

ACKNOWLEDGMENT

First of all I am sincerely grateful to the Executive Secretary of the Yellowstone Library and Museum Association for asking me to prepare this story and to the Association for its willingness to publish it.

The great wealth of observations made by many people before and during my time in Yellowstone constitute the rugged core around which many of the statements appearing here have been made, and I acknowledge with sincerest gratitude my great debt to these people. In most cases, either by direct reference or inference, credit has been given to these individuals in the discussion, and no footnotes appear.

I am especially grateful to Chief Park Naturalist David de L. Condon for his innumerable valuable suggestions, specific criticisms, careful study of the draft material in its early stages, and final review of the manuscript. Park Naturalist Francis Elmore's comments regarding form of presentation are appreciated, and to Park Naturalist Merrill D. Beal I am deeply grateful for countless invaluable comments and changes suggested during his critical reading of the rough draft. Sincere appreciation is due Assistant Park Engineer Melvin Thuring who produced from field sketches the tracing which preceded the final map, and I gratefully acknowledge the invaluable help of Mrs. Alice Quist who did much to improve the general readability of the text while typing the rough draft and final manuscript for submission to the publisher.

NORRIS GEYSER BASIN

Location and Size

The Norris Geyser Basin, at an elevation of 7550 feet is located about 21 miles south of Mammoth Hot Springs on the western side of the grand loop highway to Old Faithful, and is the first geyser area seen in Yellowstone National Park by one traveling from the north on this route. At Mammoth there are many and varied hot springs but no geysers. Norris Geyser Basin consists of approximately 50 acres of sinter deposits indiscriminately spotted with hydrothermal features. The greater part of the basin is contained within a rectangular area one mile long by one-half mile wide. It is actually more of a minor depression than a true basin, as it drops away from one rhyolite drainage slope which bounds it on the east to its western boundary, the Gibbon River. The expanse of whiteness displayed by that part of the basin generally viewed by passing motorists is regarded by some as unattractive. This barren appearance together with the strong odor of hydrogen sulphide is sufficient cause for some to bypass it and thus miss one of the outstanding areas in Yellowstone. On closer examination this basin never fails to impress the visitor with its striking display of plant and mineral color and variety of thermal features.

Discovery

The Norris Geyser Basin was the last of the major thermal

areas now embraced by the boundaries of Yellowstone National Park to be discovered by white men. One contingent of DeLacy's party of gold-seekers discovered the Shoshone Geyser Basin, in September of 1863. The Folsom-Peterson-Cook party of 1869 visited the Shoshone, West Thumb, and Lower Geyser Basin areas. In 1870 the Washburn party saw the latter two and also the Heart Lake Geyser Basin. They discovered and christened Old Faithful and many other thermal features in the Upper and Midway Geyser Basins. But the Norris area, in fact the entire vast region lying between the junction of the Yellowstone with the Gardner River and the confluence of the Gibbon and Firehole Rivers, was missed by all of these early visitors. DeLacy came in via the Snake River and left by the Madison, while both the Folsom-Peterson-Cook and Washburn parties entered by the Yellowstone River and left using DeLacy's route down the Madison and thence to Virginia City, Montana.

The records agree that white men did not see the Norris Geyser Basin until 1872, but as to whether it was Dwight Woodruff ~~of~~ or E. S. Topping or both who first saw the steam clouds rising to the south from a vantage point on top of Bunsen Peak, and whether this observation took place in July or the fall of that year, there is some divergence of opinion. At any rate these two men, having become aware of the presence of thermal activity south of Bunsen Peak, journeyed in that direction and a day and a half later discovered the area which is now called the Norris Geyser Basin. It is perhaps pertinent

to observe that Woodruff and Topping probably saw the vapor rising from the thermal ~~area~~ vents at Roaring Mountain rather than at Norris Geyser Basin, but, ~~they~~ being in an exploring frame of mind, they pressed on past these phenomena to discover the larger area further south. Shortly thereafter a party which included Mr. and Mrs. H. H. Stone of Bozeman, Montana, whose descendants still reside in that area, made the trip from Mammoth Hot Springs to Norris Geyser Basin to see this newly discovered ~~geyser~~ area. This trip subsequently took the Stone party to Yellowstone Lake and the Upper and Lower Geyser Basins, and thus it was that Mrs. Stone became the first white woman to tour this ~~area~~ region of natural wonders within a very few months after it became the first National Park.

General Description

Coming into the Norris Geyser Basin from Norris Junction, that part of the area lying immediately to the right of the road is known as the Porcelain Basin, and is generally considered the most important section of this thermal area. This opinion, however, is not whole-heartedly shared by those who are familiar with the diverse and colorful features located to the north in the Hundred Spring Plain and southward from Dr. Allen's Paint Pots to the Gray Lakes.

Porcelain Basin is an area of mixed character which contains many superheated vents, including the Black Growler Steam Vent, long recognized as the hottest vent in Yellowstone National Park, and several geysers, mostly small with one, the Valentine, approaching

first magnitude. The landscape seen and the impression gained as this basin is viewed from the highway varies greatly with the type and time of day and the season of the year. Under a high bright sun in midsummer it may appear more brilliant and monotonous than it does earlier or later in the day when it is especially colorful and interesting. The copious amount of steam is not present at midday in July, but during the cooler portions of the day and especially in winter it forms a pall of vapor, a great fluffy white blanket, making the thermal features themselves almost invisible and on occasions makes driving along the road more than a little hazardous. Viewing the basin from the road under favorable light conditions it is possible to see on the basin floor below a striking and varied display of color; the blue of deep springs contrasting with the white of the sinter; yellow of delicate sulfur deposition around some features, and a blending of yellow and blue to pale green. Red and yellow splashes of arsenic sulphides, red iron oxide, often the deep brown of heavy rust, together with the emerald green of the algal growth add vigor and brilliance to the colorful scene.

From the front of the museum the Porcelain Basin is seen to the right, or slightly east of due north; slightly west of north are seen low light colored hills bearing lodgepole pine trees, beyond which lies the One Hundred Spring Plain portion of the Norris Geyser Basin about one-half mile away. There is no trail into this area, and thus one should endeavor to explore it only after consultation with the man on duty at the museum. Forming the horizon ten miles

to the northwest is the southern segment of the Gallatin Range terminating in Mt. Holmes. Looking from the rear of the museum one would little suspect that in that direction another large, colorful and extremely interesting portion of the Norris Geyser Basin extends another one-half mile southwestward to the Gray Lakes. The three loops of the self-guiding trail which begins a short distance south of the museum area, enable one to explore this area and on a one hour trip a great deal can be learned entirely on one's own.

Thermal features in the whole of the Norris Geyser Basin are numerous, closely grouped and often superheated; as a result much of the ground is rendered weak and unreliable in its ability to permit safe travel. For this reason all visitors are cautioned to "stay on the constructed walks' in the Porcelain Basin, follow the trail meticulously on any trip into the southern part of the basin, and not to go into the One Hundred Spring Plain at all unless accompanied by one who is thoroughly familiar with that area.

Museum and Public Service

Situated on the wooded knoll arcross the road from the Porcelain Basin is the Norris Museum, a structure built in 1930, which, because of its rustic appearance, unique design, and construction of huge logs and rough stone, continually elicits much praise for itself from architects, builders and the average visitor. No serious visitor to the Norris Geyser Basin should miss this museum. From its exhibits may be gained much valuable information about the

area, and the Park Ranger Naturalist on duty is available to answer questions and regularly escorts groups of interested visitors through the Porcelain Basin. The museum is the focal point from which most visitors arrange to see the Norris Geyser Basin, either by joining the Naturalist on a conducted trip or on an exploring venture on their own.

For the accommodation of museum visitors, a large parking area is located about 100 yards northwest of the museum, and rest room facilities are provided in a building about the same distance in the rear. Drinking water is available from a fountain near the top of the stairs leading down to the highway.

Theory of Geyser Action

The geysers in the Norris Geyser Basin and in Yellowstone National Park generally are unquestionably the most distinctive natural features found in the area. To better understand them certain questions require answers: What is a geyser? How does it differ from an ordinary hot spring? What is the theory as to why geysers behave as they do?

A geyser is a special type of hot spring which at uncertain intervals erupts or gushes water upward from a vent in the ground. The height and volume of the eruption varies widely from a few inches to as much as perhaps 200 feet, a few cups full to as much as 1,000,000 gallons. The water during an eruption may take the form of a slender jet of diminutive size or a column several feet through; it may be a swirling mass of atomized and associated solid streams or sheets of

water, a formless, highly agitated splashing mass, a few or many small or large bubbles, or nothing more than a swelling dome on the surface of an otherwise quiescent hot pool. The important qualification is that some manner of eruption must take place intermittently, as it is this intermittent tendency to erupt which sets it apart from the ordinary hot spring. The type of plumbing system which exists below the surface vent of a hot spring largely determines whether it is a geyser or simply a hot spring, and upon this point rests the most commonly accepted theory of geyser behavior. In order to make this theory intelligible some explanation as to the source of the heat and the water for all thermal features in Yellowstone, whether fumarole, mud pot, ordinary hot spring or geyser, should be made.

Dr. Eugene T. Allen and Dr. Arthur L. Day in their The Hot Springs of the Yellowstone National Park state:

"------gases with excess of steam have also been expelled from solidified rock and therefore in all probability are a part of the rock and come from the reservoir which is the source of all volcanic ejecta. Such reservoirs we call magmas, masses of molten rock similar to ordinary molten lavas in every way except that they contain more water and other volatile matter." Simply stated this means that the initial source of heat is the mass of molten rock, called magma, believed to exist at an undetermined depth beneath the geyser basins which in a sense may perhaps not improperly be considered residual from the time not too far distant, geologically speaking, when volcanic forces were expelling molten rock out upon the surface of this area. Drs. Allen and Day also believe that a "zone of magmatic steam", that is steam derived from the reservoir of molten

rock below, lies above the molten rock, and that "hot springs are the result of circulating ground water heated by rising jets of natural steam". Thus the heat is accounted for, and the ground water, which is supplied to the springs by natural cracks and subterranean waterways of all kinds, is quite generally believed to be derived almost entirely from the rain and snow which fall on the surface of the area. The source of these essentials of water and heat for hot springs having been explained, the theory of how they are handled by nature to produce in one case a simple hot spring and in another a geyser may now appropriately be discussed.

This theory may best be explained by frequent reference to the accompanying diagrams, Figures 1 and 2, page _____. Each diagram shows the same zone of superheated steam, which is the zone of magmatic steam mentioned by Drs. Allen and Day. Above this in each case is shown a zone of similarly fractured rock material through which the water may circulate and seep downward to come in contact with the superheated gases, mostly steam, rising from the magma. Thus far conditions are essentially parallel. Inspection of the two diagrams, however, reveals an entirely different plumbing system below the two surface vents, a difference which is believed to be basic in rendering one a simple hot spring, Figure 1, and the other a geyser, Figure 2.

Figure 1 portrays a simple, relatively straight and unconstricted tube reaching downward from the well of the spring into which is fed seepage water from the surface gathered by the underground system of cracks and related drainage ways. At some depth, which is not known and may vary greatly from one location to another, the superheated gases, mostly steam, rising from below are presumed to come in

contact with the water in this tube and begin to heat it. Continued application of heat results in establishment of a circulating system in which the heated water rises to the surface to be replaced by the influx of cold water into the tube from the surrounding ground. Since the tube is relatively free of impediments to circulation, the heated water rises freely to the surface and the result is an ordinary hot spring which will overflow at the surface if the influx of ground water exceeds in amount that lost to steam. The temperature of the spring may vary from tepid to superheated, depending upon the volume of water supplied to the system compared to the volume of steam applied to heat it.

Figure 2 portrays a simple tube reaching downward from the well of the spring for only a comparatively short distance before it branches out into a very complex plumbing system consisting of large and small chambers in the rock and deviously routed variable-sized connecting channels. Into this system seepage water from the surface is fed and heated as described above in the case of a simple hot spring. In this system, however, free circulation of the heated water is prevented by its complexity of constricted tubes and chambers.

Authorities agree that the geyser eruption must be initiated by boiling which begins in one of the side chambers connected with the main geyser tube by a narrow passage. The bubbles thus created in the chamber are forced out by steam pressure into the main tube and thence rise to the surface. The passage of these bubbles is believed to sufficiently lighten the weight of water in the tube to allow the steam pressure in the system to expell some water from the surface vent. This in turn results in further lightening of the load and

consequent conversion of superheated water, this time perhaps in one of the other chambers, to steam and creation of additional pressure to either augment the first eruption or cause another one. Such chain reactions as this, effecting first one, then another, and finally all parts of the system eventually result in sufficient relief of weight of water in the system and consequent formation of adequate steam pressure to bring on the major eruption which clears it of most of its water. Thus relieved, the system is free to refill with water again in preparation for a repetition of the cycle.

Data from Hot Springs of the Yellowstone National Park

The following interesting information about the Norris Geyser Basin was gleaned from statements co-authored by Drs. Allen and Day found in their publication Hot Springs of the Yellowstone National Park:

1. As to the origin of the colors at Norris: "It is these colonies of algae (micro-organisms) the minor mineral deposits like free sulfur, red or brown oxide of iron, black oxide of manganese and red and yellow sulphide of arsenic, which, taken together with the blue of the clear deep springs, contribute the pigments in the beautiful natural pictures that delight the eye of the beholder at Mammoth Springs, Norris Basin and the Yellowstone Canyon".
2. "The highest content of silica (the mineral matter of which geyser cones are formed) in any springs of the Park occurs in some of the Norris waters."
3. "Why more silica does not deposit" is a question "quite beyond

our ken". In this connection it is appropriate to point out that geyser cones, such as found especially in the Upper Geyser Basin, are nonexistent in the Norris Geyser Basin.

4. On the rate of deposition of siliceous sinter they say: "Crude attempts to measure the rate at which siliceous sinter deposits have all led to the conclusion that it must be very slow". "Not only do the limits of thickness on different blocks vary greatly, from 0.1 to 2.7 mm in the Upper Basin, but also the coating on the same block is irregular, patchy in character, indeed much as we find it on the ground of the basins".

"The most remarkable deposits of silica anywhere obtained were formed at the edge of the Porcelain Terrace (Norris Geyser Basin) above the Opal Spring. ------ Two blocks were set out in the path of the running water ------ they were chopped out with a pick after a period of approximately eleven months. Across the thickest portions of the deposit, sections were sawed and measured. The maximum thickness of the sections was 24mm and 32mm respectively." Thirty-two millimeters equals slightly less than $1\frac{1}{2}$ inches.

Contrasted to this is the statement regarding the deposition of calcareous sinter or travertine, the material from which the Mammoth Hot Springs terraces are formed: "---the maximum rate of deposition in the Mammoth area was 22.2 inches per year, and the average rate 8.3 inches."

5. In speaking about the discharge of water from the Norris Geyser Basin they say: "The variation ------ runs hand in hand with the decline of rainfall."

6. The discharge of water from the Norris Geyser Basin averages less than 3 second feet compared to an average of 17 second feet from the Upper Geyser Basin.

7. They say about the amount of dissolved mineral matter carried away by the Hot Waters per day: " ------we find that the total discharge of soluble material per day of 24 hours would amount to----- 390 tons "for the entire park, and for the "Norris Basin 5220 kilograms" or about 6½ tons.

8. "Chlorine, as chloride, and gases, including hydrogen sulphide, are more abundant in the alkaline springs of the Norris area than in any other geyser basin that has been sufficiently investigated."

9. In regard to formation of sulphuric acid and its effect: "Field observations leave no room for doubt that, in warm ground, hydrogen sulphide, free sulfur, or both, are oxidized further to sulfuric acid. ------The chemical action of sulfuric acid ------ has been found to be what might have been expected; soluble rocks---dissolve; susceptible minerals of -----rhyolite, etc.-----are more or less readily attacked and the rock gradually goes to pieces."

10. Their comments on mud-pots were: "The nature of the insoluble matter in mud-pots, mostly clay and opal in a fine state of division, -----, suggests that each is derived in the same way, namely, by decomposition of the rhyolite rock with sulfuric acid. ------The study of mud-pots brings out two important points ------, first, these peculiar manifestations are simply extreme cases of the sulphate type of hot spring, the mud of which is of their own making--the insoluble

product of rock leaching by acid water; and second, scarcity of water, as an essential condition of the leaching process in all sulphate springs, is strongly confirmed."

11. Their reference to superheated steam was: "In no other area of the Yellowstone Park is superheated steam so much in evidence as at the Norris Basin." "Steam superheated at the surface must have remained superheated throughout its passage from the magma", which is the reservoir of extremely hot, molten, or potentially molten, rock existant in the earth below from which is derived all of the heat for the hot spring areas.

12. In commenting on superheated water they say: "From numerous observations it is concluded that this water rises from a hotter zone in the depths of the spring as a result of a density lower than that of the surface water. Ascending in considerable volume from a level where the pressure keeps it from boiling, it quickly reaches the surface where the reduction in pressure brings it above the boiling point."

"Slightly lower maximum surface temperatures in Norris Springs (not steam vents) as compared with those of other geyser basins are due to the general absence of superheated waters, a result of the shallower springs and the more abundant gases."

13. In comparing the relative age of the Norris Geyser Basin and the Upper Geyser Basin this is written: "The problem of the relative age of the two basins as reckoned in centuries is much too complex for us, but in the light of the whole body of evidence, ----- the Norris area, viewed either chemically or thermally, appears to represent an earlier stage of hydrothermal avtivity than that of other

geyser basins."

An observation which I made in regard to the fissuring in the rhyolite of the Norris Geyser Basin is of interest and perhaps real geological significance. During the routine work of determining size and general orientation of the surface orifices of the hydrothermal features in this basin it became apparent that there is a dominant tendency for them to display length in a northwest to southeast direction. This characteristic is readily noticeable at each of the following vents: Valentine Geyser, Ledge Geyser, Dark Cavern Geyser, Hurricane Vent, Ebony Geyser, Steamboat Geyser, Veteran Geyser, Monarch Geyser Crater, Minute Geyser, Emerald Spring, Bathtub Spring, Echinus Geyser, Perpetual Spouter, and Rock Spring. It is suggested that these surface expressions probably reflect a fundamental pattern of jointing in the underlying rhyolite of this area, and perhaps of the whole Park.

Algae in the Norris Geyser Basin

During the summers of 1932 through 1937 Dr. Arthur Nash, Park Ranger Naturalist, made a study of blue-green algae in Yellowstone National Park. The following observations and comments relative to algae in the Norris Geyser Basin substantiated by statements quoted from Dr. Nash are significant.

In the shallow running water of the Porcelain Basin Dr. Nash found several species of blue-green algae in regard to which he wrote: "Zygnema ?, sp. contributes largely to the brown coloring in temperatures between 62° and 32° C. (143.6° F. and 89.6° F.) Being a

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relatively large plant it here masks Pleurocapsa caldaria which contributes largely to a green color when it is abundant. Pleurocapsa caldaria is abundant and Zygnema is only occasional between 45° and 24° C. (113° F. and 75.2° F.) and so the coating is green. The black filamentous growths between 26° and 22° C. (78.8° F. and 71.6° F) are made by the abundance of Microspora loefgreni var suecia a comparatively large --- alga."

In one of the small streams north and west of Constant Geyser he mentions a "thin green plant coating along the entire length (about 200 feet) of stream" in waters ranging from 104° F. to 89.6° F. which "---is made green largely by the abundance of the alga Pleurocapsa caldaria---."

In Sieve Lake and its drainways he found two micro-organisms existing as "gray to brown filamentous plant growth at edges of the shallow lake and extending in small shallow stream southward about 75 feet spreading out on Porcelain Basin"" in water ranging in temperature from 77° F. to 73.4° F. "The combination of Zygnema and Microspora loefgreni var. minor seemed to make the more gray colors."

The hotter waters draining from a small spring near Ebony Geyser were found to contain a "yellow to green plant coating appearing about 10 feet from the source of the spring and extending down stream about 45 feet" in water ranging from 160° F. to 120.2° F. In this case Dr. Nash further states that: "Phormidium rubrum was abundant and Gloeothece Yellowstonense was common." Regarding algae found further down stream in water ranging from 122° F. to 86° F. which he

observed formed a "green to brown plant coating on lower slopes" he went on to state that: "Gloethece Yellowstonense was abundant, Phormidium rubrum was sparse and Pleurocapsa caldaria was sparse." Dr. Nash's writing indicates his belief in the strong possibility that the presence in varying abundance of diverse species of algae can "--- make the difference in color where indicated."

Bore Hole Investigation

In connection with the study of hot water phenomena by Drs. E. T. Allen and Arthur L. Day in Yellowstone National Park for the Geophysical Laboratory, two bore holes were drilled in geyser areas. One was in the Upper Geyser Basin near Old Faithful and one at Norris Geyser Basin. The following are sime interesting facts relative to the drilling at Norris Geyser Basin gleaned from the report of Dr. Clarence N. Fenner, who was actively in charge of the operation.

The bore hole at Norris Geyser Basin was drilled in the area of hot ground between Congress Pool and Nuphar Lake some 200 to 300 feet east of the road. The drilling was begun in August of 1930 and completed during early October, and was done by Vance Butler who had drilled several steam wells in California and elsewhere. This test hole was drilled to a final depth of 264 feet 10 inches, and by that time such critically dangerous conditions relative to high steam pressure and temperature had developed that "it was finally decided that it was futile to continue." The highest temperature encountered was 401° F. and the greatest pressure was 297½ pounds per square inch, to which somewhat less than 15 pounds per square inch should be added

to arrive at the absolute pressure.

The following information relative to the difficulties encountered in the drilling of this test hole are quoted from Mr. Fenner's report:

"In the Norris hole the rock penetrated was evidently broken by fissures and joints. This is indicated by irregularities of pressures and temperatures. For instance, on September 9, at a depth of about 244 feet, a pressure reading in the morning gave 181 pounds, but the next day, after steam had been allowed to blow off for some time, the pressure had dropped to 88 pounds. On September 11, the reading in the morning was 89 pounds. During the day a fissure was passed through in drilling, and the pressure increased suddenly to 225 pounds. The next day the reading was 250 pounds.

"The drill contractor became apprehensive that with such high pressures brought close to the surface the shattered rock would be blown out bodily and a great crater would be formed. Drilling was discontinued for several days, and a heavy mass of concrete, reinforced with iron tie-rods, was laid, covering a considerable area adjacent to the drill hole. Steam was allowed to blow off continually during this time, with no indication of diminution of pressure; in fact, a reading taken a few days later, before drilling was resumed, indicated 297½ pounds (above atmospheric pressure).

"The temperature a few hours later was found to be 401° F. The high temperature and pressure were undoubtedly due to steam coming up through fissures from a lower region. According to calculations, the pressure was more than sufficient to lift the weight of a column

of rock extending from the bottom of the hole to the surface. Apparently it was only because of the interlocking of the jointed masses that there was not an upheaval. When the thermometer was examined after the last measurement, the surface of the glass was found to be blackened and etched, though it had been wrapped in cloth and placed in an iron receptacle.

"These great pressures and high temperatures rendered every phase of the work difficult and slowed down progress very greatly. After 20 feet more had been drilled a succession of new difficulties brought operations to a final stop.

"The pressure, which had ranged from 297 pounds to 250 pounds, dropped rather suddenly to 125 pounds. This looked as if the steam were finding new outlets, and in a short time it was evident that it was breaking through to the surface. Blowouts of steam, accompanied by crumbling and ejection of ground, appeared about 25 feet to the south, and the openings increased rapidly in size, but before they reached an alarming condition, caving stopped. A multitude of other vents, ranging from minute openings to some of several feet in diameter at the mouth appeared to the west and north.

"We felt some apprehension that when the valves were finally closed and the orifice was sealed there would be an upheaval. As a possible safeguard against this, five tons of cement batter were rapidly pumped down the hole. Whether this was helpful or not, there were no serious results. Two or three hours after the valves were closed a large blowout appeared about 75 feet away, and the next day

there was another at a distance of 50 feet. These vents continued active, but the discharge was not violent, and they did not increase in size. The drill hole was sealed at the surface with concrete, and there has been no further outbreak."

Mr. Fenner kept a daily log of this drilling operation, and the following entries relative to the conditions which caused termination of the test are quoted from it:

"September 16: Depth - 246 feet 6 inches. A block of concrete was being laid at the surface. Since September 11 the valves had been wide open most of the time. At 9:35 a.m. the gauge was attached. The indicator rose almost at once to 297½ pounds. At 9:40 a.m. pressure - 276 pounds, at 9:44 a.m. 268 pounds at 9:50 a.m. 256 pounds. In the afternoon the thermometer was lowered on drill tools to the bottom of the hole, was left for 10 minutes, and then pulled up. Steam valve at the side was wide open during the operation. Temperature registered 401° F.

"September 17: Depth - 246 feet 6 inches. Pressure at 9:17 a.m. - 250 pounds. Outlet valve had been wide open all night, but was nearly shut off at 8:20 a.m. For taking pressure it was shut off completely.

"September 18: Depth - 246 feet 6 inches. Attempts to drill had been unsuccessful. A pressure reading this morning after full escape of steam during night gave 250 pounds. Later, 2 feet was drilled. A pressure reading was taken after steam had blown off all night and all day, except that it was shut off for 40 minutes before

reading was made. This gave 277½ pounds, and remained constant for 30 minutes.

September 20: At 8:00 a.m., depth - 248 feet 11 inches. Pressure - 250 pounds. At 3:00 p.m., depth - 254 feet 10 inches. After valves had been closed for 1 hour, pressure - 265 pounds.

"September 22: Depth - 263 feet 4 inches. Pressure - 265 pounds.

"September 23: Depth - 264 feet 10 inches. Pressure - 252½ pounds.

"September 24: Pressure dropped to 145 pounds, then to 125, then to 113. Blowouts appeared in the surrounding ground. Casing pipe ruptured 36 feet below surface.

"October 2: Attempts to continue work were abandoned."

As a matter of interest by way of comparison, the test hole at the Upper Geyser Basin near Old Faithful was drilled to a total depth of 406 feet at which point the maximum temperature of 356° F. and pressure of 57 pounds were recorded. When the depth of 406 feet was reached it was believed that most of the desired information had been obtained, and thus work was discontinued and the orifice sealed with concrete.

An interesting contrast between the rock material penetrated by the two bore holes was brought out by Fenner's study of the two cores. In regard to the Norris core he stated: "The material encountered in the uppermost part of the drill hole appeared to be rock debris that had been washed over the site. This was succeeded

by a mixture of boulders and sand that probably represented disintegration of rock material in place, and finally solid rock was encountered. Naturally there was no sharp boundary separating one class of material from another. A depth of 58 feet was reached before the rock became continuously solid." This solid rock is rhyolite. In contrast to this, Fenner states this about the material encountered in the Upper Basin bore hole: "For a few feet downward from the surface the drill passed through siliceous sinter, of the sort that the geysers and hot springs now deposit around their orifices and in their overflows. At a depth of about 7 feet pebbles of rhyolite began to appear, and the proportion gradually increased. At 40 feet the core consisted essentially of gravel cemented with opaline silica and secondary quartz, and from here downward the gravels were thoroughly incurated. --- The gravels probably accumulated under a large body of water. --- The gravel beds have the characteristics that might be expected of sediments deposited in lakes ponded by glacial ice. --- Altered sediments continued downward to a depth of 220 feet before rock in place was met. --- After the sediments were drilled through---the rock encountered was originally of dacitic composition as far as the hole penetrated, 406 feet."

Aside from some interesting chemical considerations which set it apart from the other major geyser basins in Yellowstone, the Norris Geyser Basin is unique in several more respects. In no other area is superheated steam so much in evidence, and it is in this basin that the highest temperatures of the entire park have been

recorded. Both superheated steam vents and geysers are found adjacent only in the Norris Geyser Basin according to the research of the Geophysical Laboratory, a condition which is presumed to evolve from the uneven distribution of the water supply to the area. At Norris Geyser Basin the zone of superheated steam seems to extend much closer to the surface than at the Upper Geyser Basin, and as a consequence the zone of ground water is thinner.

In the Upper and Lower Geyser Basins there is a marked tendency for the springs to occur close to the river, but at Norris no such tendency is found. These are some of the things which make the Norris Geyser Basin interesting and serve to set it apart from the other major geyser areas. There is yet another characteristic which has consistently impressed every observer who has spent any appreciable time in the area or returned to make observations with any degree of regularity. This is the great tendency toward more rapid change of type and degree of activity exhibited by the thermal features located in the Norris Geyser Basin. This proclivity has been observed through the years and will be apparent in the following discussion relative to the individual features. It should be especially borne in mind that what is said today regarding the activity of any Norris Geyser Basin vent may not accurately apply tomorrow or next year. The same of course is true, but to a less marked degree, of all thermal features in Yellowstone National Park.

The Names of Hydrothermal Features in the Norris Geyser Basin

More than seventy features in the Norris Geyser Basin have been given names. Their dates of origin span the years from the time of P. W. Norris to the present. Some features have been very appropriately named; in the case of others a valid reason is less apparent, and many rather important and beautiful features have not thus far been honored by a name of any kind. Of the seventy seven names here used for features in the Norris Geyser Basin, less than half are on what might be called the accredited list. That is to say, all are "accepted" but less than half of them are "approved." A name which is commonly used or one merely suggested because the need is apparent may become "accepted". But any geographic name to acquire full stature as such for use in the United States must be brought to the formal attention of and approved by the United States Board on Geographic Names. This, by the way, is an action which may require months or even years, and is accountable even now for the fact that many of those shown below must still appear on the "not yet approved" list.

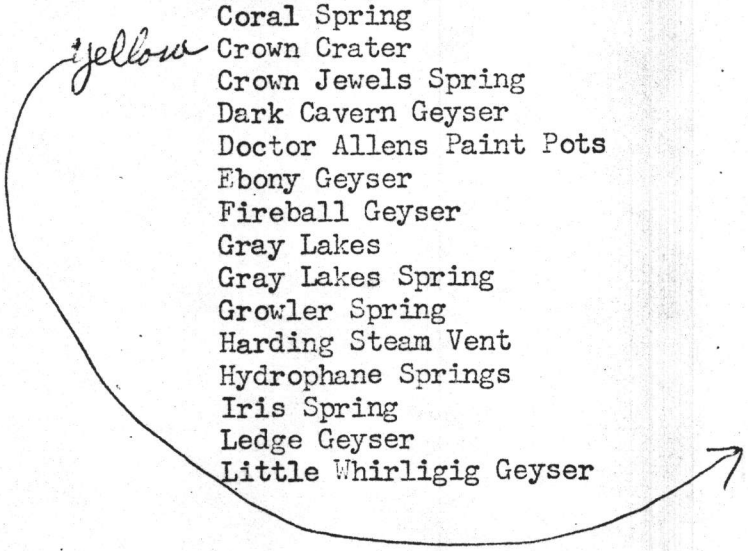
Names approved by the United States Board on Geographic Names:

Arsenic Geyser
Bathtub Spring
Big Alcove Spring
Black Growler Steam Vent
Cinder Pool
Colloidal Pool
Congress Pool
Constant Geyser
Corporal Geyser
Cradle Mud Spring
Double Bulger
Echinus Geyser
Emerald Spring
Fearless Geyser
Green Dragon Spring
Horseshoe Spring
Hurricane Vent
Little Alcove Spring
Locomotive Spring
Minute Geyser
Monarch Geyser Crater
One Hundred Spring Plain
Palpitator Spring
Pearl Geyser
Phillips Cauldron
Porcelain Basin

Primrose Springs
Realgar Creek
Realgar Springs
Steamboat Geyser
Steamvalve Spring
Tantalus Creek
Valentine Geyser
Verma Spring
Vixen Geyser
Whirligig Geyser

Names "accepted" but not yet approved by the United States Board on Geographic Names:

Arch Steam Vent
Black Hermit Caldron
Black Pit Spring
Blue Geyser
Cistern Spring
Coral Spring
Crown Crater
Crown Jewels Spring
Dark Cavern Geyser
Doctor Allens Paint Pots
Ebony Geyser
Fireball Geyser
Gray Lakes
Gray Lakes Spring
Growler Spring
Harding Steam Vent
Hydrophane Springs
Iris Spring
Ledge Geyser
Little Whirligig Geyser
Medusa Spring
Nuphar Lake
Onyx Spring
Opal Springs
Orpiment Springs
Pebble Geyser Cone
Perpetual Spouter
Porcelain Terrace
Ragged Hills
Rock Spring
Receptacle Spring
Recess Spring
Reservoir, The
Sieve Lake
Feisty Geyser
Splutter Pot
Spiny Pebble Spring
Vermilion Springs
Veteran Geyser
Yellow Funnel Spring



HYDROTHERMAL FEATURES IN THE NORRIS GEYSER BASIN

One or more representatives of every type of hydrothermal phenomena to be found anywhere in Yellowstone National Park can be found in the Norris Geyser Basin. Of the total number located in this area, perhaps no more than half have been named, and they are those which for one reason or another have especially attracted human interest. In gathering data for this publication each of the seventy seven named features was visited a number of times and observed at length in order to obtain reliable first hand information around which to build descriptive statements as to the physical appearance and mode of activity. The map made from a tracing prepared by myself in 1932 was completely rechecked in the field to adjust size and relationship of features and establish the route of the trails in the area.

The focal point from which this presentation is made is the Norris Museum; it is the location where one who is interested in seeing the Norris Geyser Basin naturally arrives. The average visitor will likely obtain what information he can from the Naturalist on duty at the museum, after which he may desire to explore the geyser basin itself. In that event it will be highly desirable to compare the descriptive matter and the map presented here, which have been designed for use together, with his own observations.

One using this publication will find in the following pages that a number has been assigned to each of the features which has an accepted name; following this number and name is the descriptive matter relative to each feature. The same series of numbers appear on the

map, each immediately adjacent to its appropriate feature in the geyser basin, and the Legend on the map lists all numbers and names. Numbers 1 through 29 are applied to features in the Porcelain Basin, the area directly north of the Museum; 30 through 43 refer to features close by the Museum and along the primary loop of the Self Guiding Nature Trail located south of the Museum; 44 through 53 apply to features along the secondary loop of this trail; 54 through 63 to those adjacent to the connecting link of trail between the secondary loop and the third loop and along the latter, which includes the features in the far southern portion of the basin; numbers 64 through 77 are assigned to features west of the highway, along the northern course of Tantalus Creek, and in the vicinity of The Reservoir far to the northwest of the Museum.

Do not be too surprised if the descriptions do not completely coincide with your own observations. They are a verbal attempt to portray my impressions of features which are rather difficult to describe at best and in addition are subject to continual change.

As you make your trip into this area of natural wonders, may I remind you that the red man who preceded you here through untold ages did nothing to mar its native charm. It is my fervent hope that you, a representative of a more advanced civilization, are determined to share his high place as a conservationist. To accomplish this objective may I admonish you to please use the walks and trails wherever possible, keep trash of all kinds in your pockets until you find a refuse can, throw nothing of any kind into any of the thermal

vents, and leave nothing but your tracks as evidence of your having been here.

This course will leave the area unimpaired for your grandchildren to see, and the resulting reduction in operating costs in Yellowstone National Park will even be apparent to you as a tax paying citizen.

1. THE BLACK GROWLER STEAM VENT is a feature of great prominence in the Norris Geyser Basin. Its location is on the southwestern rim of the crater-like pit of the Valentine Geyser immediately below and across the road from the Norris Museum. It is the noisiest vent in the entire basin, if not in the park, its location cannot be missed wherever it may move. Since it has moved during the past twenty years from one or more temporary sites closer to the road to its present location it is anticipated that it might move again.

This vent may be the successor to Dr. A. C. Peale's No. 7 which he called "Black Geyser" which he described in 1878 saying: "It is a small spouter at the head of the gulch, where the wagon-road turns to go around the group. It is in dark bluish-black deposit and spouts with a great deal of steam to the height of ten feet. The water is milky-hued, and has a strong odor of sulphur, which is probably the cause of the turbidity. The water fluctuates."

No positive evidence as to the exact origin of the present name of this feature has been found. The "black" dates back to Peale, but there is some reason to believe that the vent may not have been any too impressive to observers prior to 1890, as neither Wylie's guide book of 1882 or Haupt's of 1883 or Hyde's of 1888 even allude to it. Guptill in his 1890 guide to Yellowstone Park speaks of "The Black Growler", and since his description of the feature is in part almost a direct quote from Peale, there is little doubt that it refers to the same vent. Referring to the noise from this steam vent Guptill said in 1890: "Very little water is thrown out, while a large quantity of steam is constantly escaping, producing a peculiar sound." It appears

possible that Peale was impressed by the color while Guptill was with the sound of this vent, so the name Black Growler was born.

Save for Peale's description and Guptill's statement, little is known of the early appearance of the vent. The latter's mention of "a chimney-shaped opening" and "the deposits surrounding it being of inky blackness--" leads one to speculate on the possibility of its having been somewhat similar in appearance when located nearer the road back in those early days to what it is now, though during the period of its migration down the hill and soon after it chose the present site for activity it looked very different.

As late as 1932 I recall the existence of two major sites of activity which were alluded to as related vents of the Black Growler, as each made a great deal of noise and was known to be exhausting extremely hot, almost dry steam. One of these was a most unpretentious-appearing hole at a point perhaps fifty feet below the road and barely off the path to the right before the path crosses the little drainage on its way down into the basin. The decomposed rhyolite in which the vent existed was quite dark in appearance, but there was no deposition of silica or even a raised surface around it to suggest in any way the "chimney-shaped opening" mentioned by Guptill. The other site of activity at this time was located very close to if not exactly in the same place as that occupied by the present Black Growler. Here again it was simply a relatively small somewhat darkened hole in the decomposed rhyolite lip of the pit above the Valentine Geyser. The steam blast was dry, and during my seasonal sojourn in the Norris area

through the summer of 1935 there was little evidence, if any, of siliceous deposition around the vent.

The Black Growler now consists of six chimney-like vents, two large and four smaller located in the irregular top of the sinter mound or cone-like structure which is roughly four feet square and varies in color from gleaming milk-white through very delicate pink to creamy-buff, the whole of which has been deposited from the feature's own water during the alternate periods in which it has been active at the present location since the early 1930s. The most northerly of these six vents is the largest; it is about eighteen inches by perhaps a foot at the extremes, and very irregular in outline. The next larger vent is more regularly shaped and perhaps a foot across. Nestled close by these two, toward the left as one faces into the Valentine pit, are four smaller vents from two to four inches across, and in addition several smaller holes are scattered about in the surface of the cone.

This cluster of vents rises about two feet from the sinter base on the downhill side and six to eight inches above the altered rhyolite on the upper side. The inside surfaces of at least the main vents have the appearance of being polished smooth by the incessant rush of high pressure steam and water, yet on these a black material, possibly an oxide of sulphur, has been deposited. The red splotches on the sinter near by are probably predominately iron oxide, though it is possible that some arsenic sulphide may be present.

An integral part of this feature's formation is the sinter-covered terrace or ledge which extends about three feet northeasterly

from the base of the main cone before dropping away sharply about four feet to connect with the runoff channel into the pit. This channel is heavily sinter-covered and similarly colored to the terrace and cone above, except that it is somewhat more grayish-white at its edges and is delicate pink in the center where the water runs deepest and hottest.

The characteristic activity of this feature consists of constant high pressure discharge of steam accompanied by irregularly intermittent belches of water, which create a spluttering, swishing sound to punctuate the rather high pitched roar of the escaping gas. Very finely atomized water seems to be present in the steam blast all the time, and is augmented on the occasions of the watery belches by a heavy discharge of droplets, often to a height of ten or fifteen feet, and frequently a ragged stream of water which rains, free-falling, into the pit or reaches there by way of the runoff channel.

Writings indicate that prior to 1932, or at least in 1927, the Black Growler had but one vent located about fifty feet below the highway. Apparently then it was recognized only as a noisy and very hot steam vent about which Ranger Phillips said: "It has the distinction of being the hottest steam vent in the park with a temperature of 284°F---." Actually, Drs. Allen & Day recorded a temperature of 280°F at this vent in 1927 and M. L. Arnold recorded 257°F in 1928 after the main activity had moved to approximately its present location.

On November 10, 1951 the Black Growler's temperature, recorded with the thermometer held in the middle of the main steam blast, was 204°F. This reading was definitely something of a shock but its

validity was confirmed by other readings, none of which in any vent was above 204°F.

It should be borne in mind at this point that Park Ranger Naturalist M. David Beal stated in 1950: "---the Black Growler just isn't as hot as it used to be" after taking the temperature of one of the associated vents below and finding it to be 199.4°F. He further confirmed his suspicions in 1951 when he found the temperatures of the two associated vents were 201.2°F and 203°F. At this time, however, he did not take a reading on the Black Growler itself, which would have proven the validity of his belief.

On October 28, 1952 the temperature of the drier discharges was found to be 203°F, while that of the wet ones varied from 197.6 to 199.4°F. The boiling temperature at this elevation of about 7550 feet is about 196.5°F.

During the late 1930s and on through the summer of 1942 reports indicate that activity at the location nearer the road far outranked that displayed from the orifice on the edge of the Valentine pit. In 1939 Park Ranger Naturalist Douglas reported "---at the point the path starts down into the basin---a roaring steam vent.---On August 27th the temperature was found to be 251.6°F." In July 1941, Park Ranger Naturalist Smith reported what seems to have been the beginning of another change of location by saying: "It is believed the term Black Growler should be applied to the two vents, rather than just to the one nearer the road, as indications are that the two vents are connected. ---On July 17 the water disappeared from this lower vent, which then became the noisier of the two, causing a roaring noise so

loud that lecturing at the head of the path is inadvisable." But in 1942 Park Ranger Naturalist Replogle found that: "Black Growler did not open up to a hissing growling vent at any time during the three-month period."

Rejuvenation must have taken place at the present location during the war, as Park Ranger Naturalists Turner and Rentchler in 1946 and 1947 respectively stated "Continuously active" in reporting on the Black Growler. Unusually strong activity was witnessed by Park Ranger Naturalist Sanborn in 1948, who reported on June 21 that it "erupted steam with enough pressure to break and crack the sinter formation around the opening" and "---two steam vents broke through the ground in the vicinity of the Old Black Growler vent - between the trail and the road---. These two vents played steam and water to a height of ten to fifteen feet and continued until the afternoon of 3rd of July." This outburst by apparently related energy preceded the rupture of the adjacent highway pavement discussed later.

So, much has happened by way of change of location and appearance of this feature; perhaps it is again similar to what it was before the turn of the century.

At any rate we again have a "chimney-like hole", actually several of them, black, at least on the inner surfaces, venting steam with a terrific roar and intermittently belching water, which is not unlike Peale's description of the "Black Geyser" or Guptill's of the "Black Growler".

It could be that the feature they described now lies buried under the shoulder or bed of the improved highway, as it is a fact that considerable heat and steam is being dissipated under the road

in this vicinity. Steam, which on July 3, 1948 blew a three-foot hole in the highway pavement, demanded installation of drainage tile to the road shoulder as an avenue of escape before the highway could be repaired. This vent constantly emits steam and water, the entire road shoulder at this point steams heavily, and the oil mix on the highway surface shows the effects of the ever-present heat not far below.

The rate at which sinter deposition has taken place near the Black Growler and associated vents is a matter of interest and significance. It appears that all of the cone, terrace, and runoff channel sinter has been laid down during the intermittent periods since the early 1930s during which the feature has been active at its present location, which perhaps does not exceed fifteen years. The rapid rate of deposition has interested me for many years, but not until recently was any definite idea obtained as to just how rapidly it is taking place under favorable conditions.

On November 10, 1951 a standard engineer's stake was laid a few feet below the cone of the Black Growler in a position where it would come in contact with the runoff water and spray from the vents. This stake was recovered for examination on October 1, 1952 and found to be completely encased in well consolidated porcelain-like sinter which varied in thickness from approximately .025 of an inch to a maximum, by actual micrometer measurement, of .425 or about one half inch, which had accumulated in less than eleven months.

Associated with the Black Growler, so closely in location and action in fact that they may be considered additional surface

expressions of the same underground system, are two smaller features in the wall of the pit. One of these is northeast about twelve feet from the main feature and eight feet lower down. It is an irregularly-shaped vent about a foot across which opens upward and steams and sprays a small amount of water more or less in unison with the main Black Growler vent. It is building a miniature cone, especially on the lower side, of pinkish sinter, which merges with a similarly colored sinter runoff apron reaching some ten feet down into the pit. Northward and slightly west of the Black Growler about sixteen feet and fifteen feet below, the second of these features opens outward as an irregular vent about eighteen inches long in the altered rhyolite wall of the pit. A large amount of steam billows from this cleft all the time, and, again in unison with the Black Growler above, pulses sufficient water over its outside lip to keep a small stream flowing continuously down the gray sinter-encrusted channel to the bottom of the pit. The temperature of each of these smaller vents was found to be virtually identical with that of the wetter discharges from the Black Growler itself.

2. The VALENTINE GEYSER is located in the large pear-shaped alcove in the hillside of Porcelain Basin, about 300 feet northeast of the Norris Museum. A feature in approximately the same location was called "Alcove Spring" by Hague in 1904.

The name "Valentine Geyser" was born with this geyser on the morning of St. Valentine's Day, 1907, when it is reputed to have first erupted "and played for two hours to a height of 225 feet". This height is believed to have been estimated and therefore its validity is considered questionable. However, a winterkeeper at the Norris Hotel, C. W. Bronson, who claims to have been present at the time stated "--- large amounts of rock, mud, water, and steam were blown out, and the huge pit around the geyser was blown out" so it is evident that this first eruption was very powerful.

The vent of this geyser is located in an alcove or pocket eroded out of the rhyolite hillside. At its top this pit is approximately eighty feet across each way and oriented with its open side toward the north. It is about thirty feet deep at the south side where it rises sharply to meet the slope and as a maximum the floor is about 30 feet wide from east to west by fifty feet from north to south. Water draining into this pit from thermal features above collects as a small stream and flows northward in a six-foot channel cut approximately six feet deep through the highly altered rhyolite of the hillside. Sundry pieces of logs and limbs still litter the bottom of this pit, probable remnants of the trees present on the hillside when the geyser came into being; all these fragments are now well impregnated and encrusted with sinter.

The actual vent of the Valentine Geyser is in a rhyolite buttress which is about seven feet high and four feet across at the top. This cone-like feature is an integral part of the steep southern wall of the pit and also merges with the floor.

The geyser vent located within this rhyolite remnant is about thirty inches wide by 48 inches long in the north to south direction. It drops irregularly and sharply about eight feet, where it is about thirty inches long by eight inches wide at the south end and twelve inches at the north and almost vertical-walled. The rim is lightly covered with beady sinter and the inner surface with a smooth variety, both deep brown in color.

A review of the records on Valentine Geyser again points up the highly irregular and unpredictable character of geyser activity in the Norris Geyser Basin. In some summer seasons Valentine has been completely dormant save for gentle steaming, yet in others, such as 1936, it has been judged "one of the most regular and predictable geysers in the Park". In 1942 Valentine erupted on an average interval of seventeen hours and after observing 69 eruptions the seasonal reporter declared it to be the "most regular geyser I have been able to observe". In many seasons of observation, however, it has displayed in a month's time but one observed play and in others extremely irregular eruptions varying from as few as three in such a period to as often as one within each 24 hours. During its active phases the duration of each eruption appears to have been fairly uniform, being from one and a half to two hours on the average for the total water and steam play. The duration of the water play has varied from two up to twenty minutes,

and at the beginning of its eruption estimates up to 110 feet have been mentioned as the height to which fine beads of water are thrown. Heights based on measured angles in the course of observations by Park Ranger Naturalist Fix during the very active 1936 season varied from 55 to 105 feet. The average interval between eruptions during the 1952 season was five days. One of the eruptions observed late in October may perhaps be considered as typical of this geyser's action.

On arrival in the basin early in the day it was observed that the well was almost full of water and splashing over the rim occasionally occurred. By early afternoon splashing was sufficiently consistent to result in a meager overflow from the pit and at 3:19 p.m. the geyser broke into full eruption. By 3:35 p.m. the water eruption was virtually over except for occasional spurts of very fine spray but two hours later the steam phase, though much reduced in power, was still in evidence. The approximate height of this eruption, based on angle measurement, was fifty feet. During the first few minutes of play the discharge of water from this geyser is relatively heavy, the amount having been roughly calculated to be upwards of 15,000 gallons by Fix in 1936. Much of it drains out of the pit by way of the regular runoff channel but considerable falls as fine spray drenching a wide area.

Valentine's interval between eruptions during the summer of 1953 varied from three to ten days, but in 1954 it was seen in eruption "about once a day". During these seasons the duration of play averaged 6 minutes, not counting the steam phase which follows each eruption.

3. LEDGE GEYSER is one of the largest of the geysers in the Norris Basin. It is situated about 260 feet northeast of Valentine Geyser at the base of the slope and slightly above the general level of the floor of this portion of the geyser basin. It is in the approximate location of the feature earlier unofficially designated the "Mud Geyser", and is probably its successor.

The several related vents of the Ledge Geyser system are located in a flat basin eroded from the hillside of gray, blue, yellow and reddish-brown altered rhyolite which is roughly 50 feet across in each direction. The system of vents seems to include: the main one, a fissure about 6 feet long by from 6 inches to a foot in width oriented roughly northwest-southeast at the base of a 4 foot ledge of altered rhyolite into which dense deposits of platy sinter have been intruded. Southeast of this main vent about ten feet lies another pipe-like opening 10 by 18 inches in size, and ten feet beyond in the same direction the underground fissure opens up into a narrow surface slit about ten feet in length. Due east lies a large deep cleft in the rhyolite, the pit, which is very irregular in shape but approximately 1 to 2 feet in width by 5 or 6 feet long. This part of the present Ledge Geyser system is probably the feature formerly called the "Mud Geyser". The grayish green pool lying directly north also appears to be related to this system.

The name "Ledge Geyser" was given to this feature in 1927 by an official scientific committee appointed by the Superintendent. At that time it was described as being active from three vents, from one of which a stream was "thrown horizontally in an arc measuring

well over 100 feet while the vertical jet reaches a height of 75 feet". It was then regarded as "the largest geyser in the basin", an appellation which, through the years, has been and remains appropriate during its peak of activity. There have, however, been periods of complete inactivity, except for gentle puffing of steam from the main vent under the ledge and the sound of agitated water gurgling at depth.

Earlier descriptions of its activity, which on some occasions has come predominately from one vent and on others from another, have been so diverse that a clear picture of what constitutes a typical eruptive phase, if such there be, is difficult to obtain. In some seasons it has remained relatively quiet for weeks, then suddenly come forth with a violent muddy water eruption which lasted upwards of 24 hours.

In 1942 Ledge was in a highly active phase, eruptions occurring on an average interval of 40 hours, and it was then regarded as "not difficult to predict due to warning activity of preliminary jetting of water and steam from the angular vent." Eruptions lasted about an hour and a half, and during the first 30 minutes water was hurled spasmodically from two vents, from one on an angle to a distance of 90 feet and from the other straight up to heights varying from 20 to 75 feet. Essentially similar eruptions occurring with no degree of regularity and comparative infrequency have been reported in recent years. In 1948 it staged a series of very violent eruptions from vents associated with the fissure extending from the main vent to and including the pit on the south. These eruptions were highly irregular as to interval of time between them. In the course of the

most spectacular of these eruptions the pit "kept rocketing water to a height in excess of 100 feet" and "the Ledge Crater---went into violent action and threw a column of water a measured distance of 155 feet across the Norris Basin."

The main eruptions emanate from the vent located below the rhyolite and sinter ledge from which the feature takes its name. Prior to September 1948, this ledge extended about three feet out over the vent; however, according to Park Ranger Naturalist Sanborn, at that time the "eruption---was violent enough to break off many large sections of the heavy sinter---and throw them into the basin area."

The Ledge was highly irregular in 1952, but was relatively active when intervals between eruptions are considered on a long time basis. Such intervals have been reported as varying from as little as two days up to apparently several months between spectacular water eruptions. In 1952 intervals of 48 to 70 hours between eruptions were reported. During the eruptions water was thrown intermittently more than 100 feet from the main vent for a period of from a few minutes to three or more hours and was followed by a steam and water phase of several hours.

Heavy wash during the excessively violent eruptive phases of the recent past have cut heavily into the formation west of the runoff channel extending northward into the basin from the main vent, exposing a sharp ten-foot bank composed of: six inches to a foot of ancient dense platy sinter, one to two feet of gravelly recemented rhyolite and sinter with stringers of sinter, below which is highly altered

(white) rhyolite into which seams of sinter have been intruded.

A temperature of 204°F at each of the three orifices of the Ledge fissure was recorded on September 30, 1952.

In July 1954, Ledge demonstrated two types of eruptions: one the more or less conventional "long" eruption with duration of 30 to 40 minutes followed by a steam phase up to 24 hours in length; the other a "short" eruption with duration of only from 8 to 15 minutes which abruptly stopped, followed only by gentle steaming. An interval of three to four days usually followed the "long" eruption, while one of only 16 to 24 hours followed the "short" one before another eruption was observed. Activity from all vents of the system was observed each time an eruption occurred.

4. Another geyser of prominence is DARK CAVERN GEYSER. It is located about 75 feet northwest of Valentine Geyser at the base of the reddish-buff gravel and clay slope.

Two names, Dark Cavern Geyser and Black Cavern Geyser, have been used in reference to this feature.

A 1929 report from the Norris Geyser Basin indicates that activity at this location may have begun in that year. Wagstaff then observed: "---below the slope leading up to the Black Growler there seems to be a new geyser. It plays very irregularly to a height of 3 or 4 feet.---" During the early 1930s it was unofficially called "Hillside Geyser" and was reported to erupt on an angle as high as 25 feet. Reports of the late 1930s and early 1940s indicate consistent but variable activity. Angular eruptions were reported as high as 50 feet in 1939, and in 1941 similar eruptions every 45 minutes up to 25 feet were reported. In 1942 Replogle stated: "---was seen in play almost constantly this summer throwing water at an angle toward the alcove about twenty feet." Twenty-five to 30 foot eruptions were mentioned in July of 1946, but in August of that year it became inactive. By the summer of 1947 it was again active up to 25 feet, and in 1948 it became the subject of a detailed statement by Park Ranger Naturalist Sanborn.

He reported what he believed to be a series of preliminary eruptions every 3 minutes from two openings, one toward the pit of the Valentine which had cut a 12 inch notch into the intervening knoll. Two or more much stronger eruptions per day were reported and described "---the feature completely fills with water at which time a major eruption takes place lasting over fifteen minutes. Water is sent

well over thirty feet from the main vent and about five feet from the smaller one. ---Dark Cavern might be a good name for this, since it erupts from a dark cavern-like formation of black and gray sinter."

In 1949 eruptions of "15-20 feet about every 10-15 minutes" were reported and in 1950 Park Ranger Naturalist M. David Beal's observations enabled him to conclude that it then had a cycle of 25 to 30 minutes which included 5 to 8 preliminary eruptions coming at intervals of one-half minute and lasting one minute followed by a main eruption lasting from 8 to 10 minutes which ejected water on an angle a maximum of 20 feet. Following quiescence of from 12 to 15 minutes, another eruptive cycle was initiated. Similar activity with quiescent periods of 4 to 5 minutes was reported the following year, and my observations in late 1952 in general confirmed those of Beal.

The surface features of this geyser are very complex and difficult to describe. Most important, perhaps, is the extremely irregularly-shaped, very dark colored, beady sinter deposit which has covered several tree stumps and underlying rhyolite boulders and encompasses a 20 foot square area. A three-sided cavern roughly 5 feet deep and perhaps 4 feet wide among these boulders is first to receive the geyser's watery blast. An opening in the side of this cavern permits water to flow out and form a pool 12 feet across from which overflow twoard the west is heavy in the sinter-lined channel during the heaviest eruptions. Intermittent heavy gushes of water driven by strong steam pressure directed southeasterly against the wall of the cavern cause a characteristic thumping noise audible for considerable

distance. The water, thus smashed to bits in this seething chamber, adds to the din with much splashing and splattering before finding egress through several sinter-lined extremely irregular large and small orifices in the form of flying droplets or ragged jets blasted skyward at sundry angles. One of the latter, which often extends itself 30 feet or more on a low angle reaching into the pit of Valentine Geyser, has ripped a notch more than 3 feet deep in the altered rhyolite rib separating the two features. Other less powerful jets rise 3 to 5 feet at sundry angles above the formation. All in all this geyser in full eruption presents an extremely fascinating audible and visual performance, and the dark honeycombed structure of grotesque sinter forms with their included silicified logs is most interesting. Its temperature during eruption in the fall of 1952 was 198°F.

5. One of the most popular of all Norris Geyser Basin features is LITTLE WHIRLIGIG GEYSER, which is located toward the western side of Porcelain Basin about 410 feet north of Valentine Geyser. Its pool when full is very close to that of the Constant Geyser, whose vent lies about 50 feet northeast of it, and to that of the Whirligig, which has its vent about 40 feet to the north and slightly west.

Neither the origin of the name nor the time at which this feature first became active as a geyser has been determined. Seasonal reports of thermal activity in the Norris Geyser Basin first mentioned a small geyser at this location in 1932, and the name "Energetic" was

suggested. In 1933 it was referred to simply as "a little un-named geyser". In 1934 it gained somewhat more prominence; some relationship to the Whirligig was suggested, and the statement was made: "it--- must be a sort of little brother---". Probably its proximity to and an assumption of possible relationship of activity to the larger feature accounted eventually for the name, "Little Whirligig", which came into usage in 1937. In 1938 it was not the subject of reports, but in 1939 it came back into the Norris picture as "the most popular feature of the basin, erupting 15 to 25 feet at intervals of 10 to 20 seconds" during the eruptive phase. This statement remains as a fairly accurate summation of this excellent little performer's popularity and general activity right up to the present time.

The circular pool of the Little Whirligig is about 35 feet across, very shallow at the edges and not much over a foot deep over the vent. The surface of the sinter in this flat basin and that which forms a pebbly rim around it is colored quite uniformly brown by iron oxide. The vent, located toward the south side of the pool, is roughly elliptical, about a foot across, and opens under a projecting sinter ledge which diverts the water on an angle during eruptions. The runoff channel is located on the south side.

Prior to an eruptive phase the pool fills slowly. Each burst of the eruptive phase is preceded by a rather pronounced bulging of the water above the vent, after which water is blown into the air as an assemblage of jets which with rapid surges quickly mount higher and higher in a ragged column on an angle of about 70 degrees toward the northwest to heights of from 10 to 20 feet. The average height of

several measured bursts was 15 feet. Following each burst a minor flood of water surges down the overflow channel. The pattern of concentric waves which emanates from the vent following each burst is interesting and fascinating to watch and has built a neat miniature rim of shelly sinter around the edge of the pool. The surge of water back over the vent following each burst produces a sucking and spluttering sound, actually a minor eruption. When the eruptive phase is over the water drains slowly from the pool and eventually out of sight down the vent, leaving the basin dry for a period which has been observed to vary a great deal.

During the fall of 1952 four consecutive eruptive phases of this geyser were closely observed and the only consistency noted was the duration of each separate burst, which seemed to be from 3 to 4 seconds. Once the phase was in full swing the interval between bursts varied from 7 to 12 seconds, but toward the end this interval lengthened up to almost half a minute. The total length of these eruptive phases varied from 22 to 45 minutes and the number of separate bursts from 85 to 131. There was no consistency in the length of interval between eruptive phases; in this case the variation was from 45 minutes to 1 hour and 22 minutes.

There are indications that the activity of this geyser and the Whirligig are interrelated, but observations thus far have failed to definitely establish the degree, character, or consistency of this relationship.

The temperature of the water near the vent during eruption of the Little Whirligig was 181°F.

6. Another of the better known Norris features is the CONSTANT GEYSER. It is found toward the western side of Porcelain Basin, about 450 feet north of Valentine Geyser.

P. W. Norris is given credit for the name "Constant", it being one of the eight names used by him when speaking of features in the Norris Geyser Basin in his report of 1881. In 1890 Guptill's Guide referred to it as: "---the Constant or Minute Man, which has an eruption every 60 seconds". Norris recognized both the "Constant" and the "Minute Man", two separate features, yet Guptill's guides and those of this lineage did not recognize them separately until 1910. It is probably Peale's Spring No. 15 about which he said in 1878: "---a constant spouter, throwing a mass of water 5 feet into the air, and occasional spurts 15 to 20 feet."

The pool of this geyser is irregularly circular and roughly 40 feet across when full. The outer portion in general is quite shallow, there being an irregular marginal band which varies in width from about 2 to 6 feet over which the water lies from 2 to 6 inches in depth. The eruptions take place from an irregularly triangular-shaped vent of undetermined dimensions which lies somewhat off-center in the pool.

This geyser's activity, or lack of it, has consistently been a part of seasonal reports since 1929. A study of these reports reveals that its activity has certainly been "on again, off again" in character, and that a wide variety of eruptions have been observed as to height, duration of play, and interval. In some years it has been completely dormant; in others it has erupted one or two times a week;

then, staging a vigorous rejuvenation, it has displayed activity comparable to that observed by the earliest white visitors to the area.

Constant was very active in the fall of 1952 at which time I observed many eruptions. Rather close observation at this time revealed that the eruption begins with heavy boiling at the vent accompanied by a conspicuous bulge of water which quickly bursts into the eruption proper, during which a large column of water is raised fountain-like to a height of from 20 to 30 feet. Actual measurement based on angles showed the average of several typical bursts to be 30 feet in height. This particular eruptive phase began with a single eruption which was not followed by another until almost an hour and a half later; the third burst followed in 6 minutes, the next within 2 minutes. From then on for half an hour burst followed burst with an interval of from 50 seconds to 2 minutes, each one lasting from 5 to 8 seconds. In the course of another eruptive phase, which lasted 1 hour and 25 minutes, 68 separate bursts were counted. The temperature during eruption was 167°F. well toward center of the pool. In 1884 Hague's party recorded 197.6°F. when collecting a water sample for analysis.

Of interest is the fact that Little Whirligig often stages an eruptive phase coincident with that of the Constant, during the height of which the former may display 5 or more bursts to 1 from the latter.

7. The WHIRLIGIG GEYSER is located toward the western side of Porcelain Basin, about 440 feet north of Valentine Geyser.

The name Whirligig was given to this geyser in 1904 by Arnold Hague and reports of its activity or lack of it appear in all available reports from the Norris Geyser Basin.

It has a pronounced funnel-shaped surface well with gently flaring edges which merge into a steep-walled irregular cone terminating in the vent itself. The flare of the basin has a pronounced protuberance toward the eastern side near the upper edge of which, toward the south, there is a pipe-like vent about 2 inches across. The pool when full stands above the pipe vent, is about 30 feet across and roughly circular in shape. The spiny sinter which adorns most of the flared portion and walls of the surface well is normal gray in color, quite in contrast to the deep rust-brown displayed by the diminutive neighbor, Little Whirligig Geyser, immediately to the south.

Apparently as a geyser it was a dormant feature in the summers of 1931, 1938 and 1942, and since many reports do not mention eruptions until well along into July or early August there is some indication that it may not be any too active during the winter months. Some reports show activity as early as mid-June, however, During the periods when it has been recognized as being in an eruptive phase it has displayed great diversity with respect to interval between separate eruptions, duration of play and height. The interval according to various reports has varied as follows: one eruption in several days, one eruption a day (observed in daylight), two eruptions in a day, 5

to 6 hours between eruptions, an average interval of 1 hour and 40 minutes and an interval of 1 hour and 25 minutes. During some of its less active periods the height of eruptions has been as little as 5 feet and at other times it has been reported erupting up to 20 feet. The duration of play, too, has varied from as little as 4 up to 30 minutes.

Whirligig's mode of eruption has varied a great deal too, but those noted in the fall of 1952 were foretold by the appearance of water pouring up through the pipe vent at the same time rising in the main crater. This filling took place gradually, only the last 30 seconds before eruption being rapid and accompanied by heavy boiling in the center of the pool. The eruption proper followed in the form of upward and diverse directional blasting of ragged watery masses in such manner as to give at least an illusion of rotary action. Beginning almost at the same time and accompanying the action of the larger vent came the intriguing and characteristic steady loud puffing of steam from the pipe vent, now covered by several inches of water, and the expulsion of jets of water 2 to 3 feet on an angle toward the east. Heavy waves set up by the eruption create an interesting concentric pattern which washes the pebbly sinter at the margin of the basin. Following the eruption the water receded into the vent with pronounced whirlpool action, the surface of the pool becoming relatively static when about 6 feet across. Complete draining was slow from this point, and slow refilling began soon thereafter making a pool again about 10 feet across one-half hour after the close of the eruption.

In the course of these observations the interval between

eruptions varied from 1 hour and 49 minutes up to 2 hours and the duration of eruption from 4 to 7 minutes. The highest beads were not thrown more than 8 feet into the air and the temperature of the water during eruption was 181°F.; between eruptions the temperature was 158°F.

8. The SPLUTTER POT is in Porcelain Basin approximately 40 feet northwest of Whirligig Geyser's vent and 480 feet almost due north of Valentine Geyser in the runoff channel from Sieve Lake and Pinwheel Geyser.

Men working in the basin since 1946 often used the name "Washing Machine Geyser" in speaking of this feature.

It is an interesting thermal feature with an irregularly-circular approximately 12-inch vent in the dense sinter which opens into a larger chamber a few inches below the surface. Its action may not technically justify use of the term geyser. The spluttering or belching discharges from the vent, which are referred to as eruptions, appear to be largely dependent for water upon that supplied from the channel which pours surface water into it to fill the chamber. High pressure steam injected into this reservoir from below results in pretty continuous agitation of the water and spluttering ragged discharge of much of it back into the surface channel. There seems to be some doubt as to whether the feature is supplied with much water from subterranean sources. The ragged jets which constitute the eruption take place at an angle of about 60° toward the west, and, depending upon the volume of water pouring into the vent from upstream, vary in

frequency from "almost constantly" to none "when it was drowned out by water from the Pinwheel"; the height of the jets varies from 2 to 10 feet.

9. PINWHEEL GEYSER is located in the northwest corner of the Porcelain Basin about 500 feet south of Sieve Lake and about 550 feet north of Valentine Geyser.

The name was accepted by a Superintendent's Committee in 1927. It has also been called "Baby Grand Geyser".

Its pool, when full, is roughly pear-shaped and is a maximum of 30 feet across in each direction. The main vent appears to be a ragged cleft in the sinter about 2 by 12 feet oriented roughly north and south across the east end of the pool. The eruptions take place from the entire length of this cleft, and the water is thrown at wide angles and in all directions. The runoff from the pool toward the south during eruptions is heavy. After the eruption water pours back into the vent from the pool and from the Sieve Lake drainage, and within 8 minutes after the eruption the surface pool is again full. Eruptions often throw water across the walk, and observers are thus cautioned not to approach the Pinwheel too closely during the eruptive phase.

It is evident that this geyser, like so many other features in this basin, has had periods of unreported activity in the past, but the records indicate that its present activity had its beginning either during the war when observations were rarely made or during the early part of the 1946 season.

In July 1946 geyser activity was first reported in this location, eruptions up to 60 feet with intervals varying from 10 to 30 minutes having been observed. It became inactive again in early August, but during the 1947 season it was reported as regularly active every 10 or 15 minutes to a height of 30 feet. Lacking an officially accepted name, it was called Baby Grand Geyser by Service personnel located at Norris during the summer of 1948, at which time it was reported to be erupting about every 20 minutes early in the season, but on an interval of 45 to 60 minutes later on. Reports in 1949 mentioned no activity of this geyser, but in 1950 renewal of activity was reported on June 30th with the statement: "eruption lasted for about 5 minutes and the water thrown out was very muddy and foul smelling". In 1951 it played about once an hour to an estimated height of 30 feet for a period of 5 to 8 minutes during July. Similar occasional eruptions were reported in 1952, and on September 17th, 1952, I observed four consecutive eruptions which were an average of 1 hour and 18 minutes apart and lasted for an average of 3½ minutes. Angles read on the beads at the top of the eruption showed the height to be about 18 feet.

The activity of this geyser is materially influenced by the drainage from Sieve Lake, as it lies directly in this channel. It appears that during especially wet periods this runoff is sufficient in amount to retard if not completely eliminate eruptions of the Pinwheel Geyser.

10. FIREBALL GEYSER is in Porcelain Basin approximately 450 feet northeast of Valentine Geyser and about 130 feet east of Whirligig Geyser.

Fireball was accepted by a Superintendent's committee in 1953 to designate the small geyser here described.

Eruptions at this location take place from three small vents. One is about 6 inches in diameter, while each of the others is about 2 inches across; one is located about 12 inches and the other about 18 inches north of the main orifice. The rust-colored runoff channel toward the southwest joins that from one of the rather large unnamed pools near the walk to the east.

Eruptive periods in the fall of 1952 seemed to be about 10 minutes in length, but no interval between them was determined. During eruption water is sprayed upward as much as 2 feet from all three vents, with beads reaching a height of about 6 feet. Following the main eruption considerable water continues to be splashed out of the largest vent. The temperature of the water during eruption as recorded in 1952 was 201.1° F.

11. The PRIMROSE SPRINGS in Porcelain Basin are approximately 550 feet northeast of Valentine Geyser and 300 feet northwest of Congress Pool; they are less than 50 feet northeast of the trail in an area of highly altered rhyolite somewhat above the general level of the basin floor.

Hague used the name "Primrose" in his 1904 atlas to designate a spring north of Congress Pool near Nuphar Lake which subse-

quently degenerated to a status of relative unimportance. In 1927 a Superintendent's Committee applied the plural of the term to the springs here described.

Among several thermal features in this immediate area, two pools are the most prominent. One of these is about 7 feet across and circular in outline with steeply sloping black walls and a rust-colored rim of smooth sinter about 8 inches wide. The inner half of the pool's surface frequently boils upward about 12 inches. There is considerable overflow down the brown sinter-encrusted channel toward the northwest. The temperature of the water in this pool was 199.4° F. in the fall of 1952.

The second pool is somewhat larger and about 30 feet further north. It too is circular in outline with a diameter of about 10 feet. It is about 4 feet deep, and in general displays a light grayish-green color, except for the rust-brown band 2 to 4 inches wide around the smooth silica rim. The surface of the pool is relatively calm, but a constant quiet ebulition is apparent and active gas jets can be seen in the bottom. Some overflow takes place down the smooth heavily rust-colored encrusted channel toward the north. The temperature of the water in this pool in 1952 was 192.2° F. The runoff stream at about 15 feet from the pool is temporarily restrained and spreads thinly over a large flat pinkish-buff colored area before flowing on to join the main drainage.

12. ARSENIC GEYSER in Porcelain Basin is approximately 450 feet northwest of Valentine Geyser and 150 feet east of Little Whirligig Geyser; it is about 50 feet northwestward from Colloidal Pool, into which it drains.

The feature to which the approved name now alludes, by decision of a Superintendent's Committee in 1953, possibly may not be the one to which Hague referred in 1887 as "Arsenic Geyser"; he did not specifically locate it then, and the Atlas of 1904 simply shows "Arsenic" with reference to no certain feature. That he did have a specific geyser in mind, however, appears certain, as Allen and Day in Hot Springs of the Yellowstone National Park credit him by saying: "It was around Arsenic Spring and Constant Geyser that Hague discovered scorodite (a mineral containing iron and arsenic) in small green particles-----." This geyser has also been called "Fan".

The vent of this geyser, located in dense gray sinter, is about a foot across, and opens into a steep-walled pipe-like chamber of similar diameter in which water usually stands at a level 2 or more feet below the surface between eruptive phases. There is some deposition of sulfur around the orifice, and well developed spiny geyserite is present, especially on the east side where splashing of water is more consistent, and in the runoff channel.

Great irregularity in duration of eruptive phases and interval between them is characteristic of this geyser. The eruptive phases vary in length from 2 to 30 minutes and in frequency from

"several times daily" in 1950 to "none observed" in 1953. During an eruptive phase water is blown out at very erratic intervals on a slight angle toward the south as ragged, fountain-like jets to heights which vary from a foot up to 15 feet. Between major bursts often many minor splashes occur. In 1950 Beal recorded a temperature of 201° F. in the water of this geyser; in the fall of 1952 I found the same temperature during eruption and immediately thereafter, but just prior to an eruption phase 203° F. was recorded.

13. COLLOIDAL POOL is in Porcelain Basin about 300 feet northeast of Valentine Geyser and about 250 feet northwest of Congress Pool.

This pool was so named in 1937 by Dr. C. Max Bauer, former Chief Park Naturalist in Yellowstone National Park, because: "Its water contains large quantities of finely divided kaolin and silica which seems to be constantly in suspension."

It is a very large and rather oddly shaped pool or pond somewhat more than 100 feet long in the northwest to southeast direction by about 60 feet across at the widest place. It receives the drainage from several features to the north. Usually the water is very muddy, but early in some seasons it is quite clear and blue. Ebulition varying in strength from mild bubbling to minor eruptions which raise a considerable amount of water a foot or more upwards is consistent at a point toward the southeast end. The temperature of the water is 164° F.

14. HURRICANE VENT is about 300 feet northeast of Valentine Geyser and 225 feet west of Congress Pool, in the slope on the south side and somewhat above the level of Porcelain Basin.

This large thermal feature was named by Arnold Hague prior to 1890.

It is a steep-walled rectangular vent roughly 32 feet long in the northwest to southeast direction by 15 feet across. The hillside above of gravelly rhyolite funnels downward to meet the abrupt more solid but highly fractured walls of the vent upon which there is some deposition of sulfur and marked evidence of weathering. One large boulder appears to have slumped into the pool from the western wall of the pit. The water level in this vent fluctuates somewhat from season to season but is usually about 10 feet below the edge of the steep northeastern wall. It is always murky in appearance because of the presence of much finely divided kaolin and silica and varies in color from dark gray to grayish green. Heavy boiling on the west side keeps the surface in constant agitation. All in all it is a rather awesome feature even hotter than it looks, the temperature of 201° F. being well above the local boiling point.

Another and perhaps one time quite similar vent is suggested by the now gravel-filled depression which lies about 10 feet to the west.

15. Yellow CROWN CRATER in Porcelain Basin is about 650 feet northwest of Valentine Geyser and about 200 feet southeast of Ebony Geyser.

This feature was given a different name by Peale in 1878; in his description he said: "No. 37. Yellow Crown Spring. This is a lemon-yellow-hued mound spring, with an oak-leaf shaped margin. The basin is 2 feet deep and sulphur-lined. ---Bubbles escape gently from the small central orifice." The Hague Party recognized it simply as "Crown" in 1904, and it is thus assumed that by then it may have become inactive. The present accepted name was given by a Superintendent's Committee in 1927.

This crater is an interesting roughly circular flat-topped cone-like feature about 5 feet across which stands from 6 inches to a foot above the surrounding sinter surface. The irregularly round basin within the cone is surrounded by a very flat rim varying from 6 inches to a foot in width reaching to the edges of the cone, which is filled within an inch of its top with shelly sinter in which grass now grows. The wide flat rim suggests that the water level in the basin was static with a very meager overflow during a very long period. It is apparent that the orifice from which Peale reported "bubbles escape gently" finally sealed itself off almost completely by depositing sinter within itself. I found the last vestige of this opening, a tiny crack emitting the faint sound of water and warmth into the 6 inch, sharply tapered funnel-like cavity above which was filled with firmly compacted sand.

16. CROWN JEWELS SPRINGS are just outside of the fringe of trees about 725 feet northwest of Valentine Geyser and 150 feet southeast of Ebony Geyser; they are about 75 feet northwest of Crown Crater.

The interesting sinter formation in and around these springs and their proximity to the dormant Crown Crater suggest a certain propriety for the name which was accepted by a Superintendent's committee in 1953.

One of these springs is a shallow basin 6 feet across with a finely beaded sinter rim about 2 inches high beyond which for a distance of 6 inches to 6 feet the gently sloping surface of the mound on which it is located is clothed in highly developed botryiodal sinter. Lying in the basin are large numbers of gray, also some yellow and brown, well-rounded, sinter-covered pebbles ranging in size from $\frac{1}{4}$ inch to 1 inch, and some cobbles up to 3 inches beautifully coated with spiny sinter. Toadstood-like sinter forms in a variety of sizes are growing in the runoff channel which drains toward the south. The irregularly-shaped 6 inch vent in the middle of the basin tapers to about 3 inches, and from it water is erupted in erratic bursts about a foot into the air. About 6 feet toward the southwest another apparently related vent opens under a ledge of sinter into an irregularly elongated 4 foot basin with a low rim of spiny sinter. Rather continuous burping takes place from this vent more or less in unison with the activity of the adjacent spring, which lifts considerable water upward about a foot and throws water droplets 10 feet sidewise toward the north.

There is a definite relationship between the activity of these two springs, and since they have been observed when no water action was taking place at all, they perhaps should be considered as small geysers rather than simple hot springs.

17. EBONY GEYSER is about 880 feet northwest of Valentine Geyser and about 160 feet back in the forest from the closest edge of the sinter flood plane which includes the extinct Crown Crater.

This geyser apparently did not exist at the time of the first observations in the Norris Geyser Basin but by 1904 a spring in this location was recognized and named "Ebony Spring" by Arnold Hague. When this spring first displayed geyser activity is not known but it was at least as early as 1927, and records since that time show consistent but highly irregular geyser activity. The name was accepted by a Superintendent's Committee in 1927.

Ebony Geyser is in an alcove eroded out of the reddish brown altered rhyolite hillside. The floor of this alcove is approximately 25 feet across in each direction and the walls on three sides rise rather sharply for about 6 feet before flaring outward and upward on a gentler angle to merge with the slope which is well covered with lodgepole trees varying in size from 3 to 20 feet in height. Drainage from this basin is southward into the eastern branch of Tantalus Creek.

The surface well of this geyser is a cleft in the rhyolite about 6 feet long from northwest to southeast varying in width from 1½ to 3 feet and opening irregularly straight down about 6 feet. Its surfaces and that of the rhyolite gravel around it are well encrusted

with both beady and smooth deposits of gray sinter. This deposition is laid out in an irregular pattern varying in width from 2 to 10 feet outward from the vent; much of the sinter is a beady crust on the rhyolite gravel. Eight rhyolite boulders from roughly 18 inches average dimension up to one about 2½ by 4 feet, all highly weathered and dark reddish brown, lie on the floor of the basin north of the vent. Numerous pieces of highly silica-impregnated wood lie nearby and six dead trees, roots and all, have fallen into the pit from the forested hillside. Siliceous impregnation of the broken stubs of the limbs protruding from these old logs has pried the wood fibers apart in a manner suggestive of the bristles of a coarse-bristled brush.

Great diversity in activity of this geyser has been reported with respect to interval between eruptions and duration and height of eruptions but it has not been dormant during any reporting period. The interval has been reported as short as 2 hours and as long as "occasionally"; within one season it has been recorded for periods as erupting about every 8 hours, followed by a period when eruptions were not known of oftener than once in from 2 to as long as 4 days. The reported duration of eruption has been generally from 3 to 8 minutes but in some seasons durations of from 10 to 15 minutes seem to have been common. The height of the eruptions have been variously reported from 10 up to 75 feet.

During the 1952 season Ebony erupted on an average of three times in 24 hours, a typical eruption being foretold by water, which can usually be heard and seen deep in the tube, rising to within a foot or so of the surface accompanied by heavy boiling. Soon thereafter comes the eruption consisting of a mass of ragged 5 to 10 foot jets of water culminating in a central broken column being raised to

maximum height, which in the cases observed, though not measured, is believed not to have exceeded 25 feet. Each eruption was over within 5 minutes, in the course of which a large amount of water flowed down the overflow channel. The vent steamed gently following the eruption and water could be heard churning deep below, but no violent steam phase followed.

18. CONGRESS POOL is about 500 feet northeast of Valentine Geyser and about 400 feet southwest of Nuphar Lake, on a clay flood plane below the forested slope. It is one of the features nearest the road.

This feature apparently was named by Hiram M. Chittenden, who in writing about it, stated: "Came into existence in the winter of 1893. Like the memorable 53rd Congress, for which it is named, its performance is sadly incommensurate with its promises." Guptill's guide book in 1894 says of its early activity: "The first eruptions were of great force and completely blockaded the road with masses of earth and formation. ---The diameter of the same is about thirty feet. Its pale blue water is in a state of violent agitation, rising nearly to the rim of the crater with a slight overflow."

It is an almost round basin 30 by 25 feet in greatest dimensions with a high symmetrical rim built of mud expelled from its own vent. In these days it usually contains grayish-blue water, or a thin solution of mud in a state of quiet ebullition, or a sun baked mud flat. The water temperature in the fall of 1952 was 143° F.

19. LOCOMOTIVE SPRING is approximately 70 feet southeast of Congress Pool on the clay flat at the base of the weathered rhyolite slope; it is closely associated with the Vermilion Springs, which rather surround it and extend beyond and up the hillside.

The name as originally applied to a feature in the Norris Geyser Basin is old, actually dating from before Peale's work in 1878 who then observed: "A stake with the name Locomotive was found near the spring, probably put there by someone of the party when building the wagon road. ------it is across the road from No. 1 on somewhat higher ground." In his list of names Peale refers to it as No. 6, Locomotive Spring", but his map shows "Sulphur Mud Spr. 6" at the location mentioned. His bearing and distance of this feature from Emerald Spring, as shown on the 1878 map, plotted on either Hague's map or the one used in this work spots a location about half way between the Norris Museum and the parking area near the rest rooms. There being no evidence of there ever having been a thermal feature in this location, speculation regarding the possibility of "Locomotive", Peale's "Sulphur Mud Spr. 6", and Hague's "Steamvalve" being one and the same feature does not seem too inappropriate . The variation in location is not sufficient to preclude the possibility that each mapped the same spring and gave it the name which appealed to him. At any rate, the early "Locomotive" spring definitely was not in the same location as the one to which Hague applied this name in 1904. It was used by him to designate some feature near Congress Pool, exactly which one, however, is not made clear by his map. The

Superintendent's committee in 1927 accepted the name for "--- a boiling sulphur mud hole near Congress Pool-----."

This spring is a large irregularly-shaped elongated basin 15 feet wide by 25 feet in length from northeast to southwest with a steep yellow-tinted clay rim which usually stands several inches above the turbid yellowish water. Strong boiling action is evident, especially at the northern end where the temperature was 199° F. in 1952; at the opposite end the reading was 190° F. A frying pan area adjacent to the northern end also had a temperature of 199° F. It appears that the water level may fluctuate somewhat in the large basin, but apparently there is little if any overflow.

20. VERMILION SPRINGS are southeast of Congress Pool on the flat and up the slope 125 feet; they are mostly beyond and also on the slope above Locomotive Spring.

The name was originally used by Peale to designate a spring about 120 feet northwest of Echinus Geyser. Hague did not recognize it, but a Superintendent's committee in 1927 accepted the name for a spring much further toward the west. This spring, however, long since having deteriorated into a feature of no importance, was declared nonexistant by a Superintendent's committee in 1953. This committee accepted the name Vermilion to designate the springs here mentioned.

Overall the area of these springs is one of dangerously thin crust and blistering hot activity expressed at the surface in a variety of forms on the flat and the slope of the adjacent hill,

both of which are composed of rhyolite in an advanced condition of alteration. Turbid puddles, mud and paint pots of various sizes, frying pan areas, sizzling steam vents and dry gas fumaroles scattered all over the place render the entire area unsafe to walk upon except with the greatest caution. Around several of the springs the vermilion-red and rust-brown of iron oxides are dominant colors, and the yellow of sulfur is abundant.

21. ONYX SPRING is in Porcelain Basin about 750 feet northeast of Valentine Geyser and 425 feet northwest of Congress Pool.

A feature in this location appears on Hague's map of 1904, but not until 1927 when names for several hot springs in this basin were suggested by a Superintendent's committee did it receive the name Onyx.

It is a very pretty large shallow pool 21 feet across from northeast to southwest by 18 feet in the opposite directions. The dominant color is grayish-blue, but a band of variable width from 3 to 12 inches composed of broken sinter slabs colored a rich brown adorns the entire circumference of the pool from the edge of the water inward. There are two vents; the larger of these is located about center of the pool and is about 3 feet across, bordered by a rust-brown band a foot wide inside of which the color is grayish-blue. The smaller vent is some 3 or 4 feet toward the northwest from center, about a foot across, and brownish-gray in color. Gentle ebullition above both vents, with the smaller showing a bit more vigor, seems to be the normal action of this spring, and there is a slight

overflow toward the northeast to join that from Blue Geyser. Stronger activity in the vents which perhaps on some occasions causes relatively strong wave movement toward the margin is suggested by the presence of a miniature levee of gravelly sinter raised just beyond the normal water edge of the pool. Also, old reports prove that Onyx, like most features in the Norris Geyser Basin, at one time or another depart, often extremely, from what has been considered normal behavior. In 1929 one observer reported: "Onyx Spring turned from a quiet bubbling hot spring into a roaring steam vent with a temperature of around 198° F." In the fall of 1952 the temperature of the larger vent was 161.6° F. and that of the smaller one was 154.4° F.

22. BLUE GEYSER is 750 feet northeast of Valentine Geyser and about 420 feet almost due north of Congress Pool in Porcelain Basin.

This feature appears to have come into prominence in relatively recent years and was given the name, which is now accepted, by a Superintendent's Committee in 1927. Just why it was designated as "blue" is not apparent at this time.

The pool of this geyser is nearly round and about 24 feet across. In general the sinter is very dark in color, actually almost black, over much of the inner area covered by the pool. Toward the margin there is a yellowish-gray band which varies in width from 1 to 3 feet and yet further out the color is light rust-brown. The vent, located about in the center of the pool, appears to be about 8 feet across.

Heavy boiling is consistent above the entire area of the vent during which the water rises upward from 1 to 2 feet as a seething mass of bubbles. Intermittently, with no apparent regularity, more violent eruptive bursts occur which raise a ragged irregular mass upward as much as 10 feet. Wave action in concentric pattern from the vent toward the margin of the pool is consistent and heavy, especially after the major bursts. These waves cause some overflow toward the west and also into the pool of Iris Spring, with which it merges on the southwest. The temperature during most active ebullition was 200° F.

23. IRIS SPRING is about 730 feet northeast of Valentine Geyser and about 400 feet almost due north of Congress Pool in Porcelain Basin. It is within 20 feet of the Blue Geyser.

A feature in approximately this location carries the name "Iris" in the Hague atlas of 1904. A Superintendent's committee in 1953 agreed that the one here described should be called Iris Spring.

The pool is about 10 feet across but actually of indefinite extent because of its tendency to merge across a watery flood plane with the wave wash from the Blue Geyser immediately adjacent on the northeast. The pool is yellowish-brown toward the center and darker brown toward the outer margin. The water above the irregular cobbly vent is in a consistent state of ebullition and jets or splashes up to perhaps a foot occur intermittently. The temperature in the vent during ebullition is only 167° F. and thus it appears that gas pressure other than steam must account for the agitation and minor eruptions.

24. FEISTY GEYSER is approximately 700 feet northeast of Valentine Geyser and about 250 feet slightly east of north from Congress Pool in that portion of Porcelain Basin between Blue Geyser and the highway.

Being hidden from the museum and also from the trail in Porcelain Basin, this little geyser's activity has not come in for much notice; its eruptive tendencies are believed to have become more pronounced in recent years. These factors apparently account for its not having inspired a name prior to 1953.

This small but very active geyser erupts from a symetrically-shaped, sinter-lined pipe-like vent about a foot across in the smooth sinter surface of the basin floor. In and around a small and shallow basin on the southeastern side the deposition of brown iron oxide is quite noticeable. An eruptive phase appears to be very long; actually this geyser seemed to be always in eruption while I worked in sight of it in 1952. It did, however, display a rather characteristic tendency to falter momentarily in its determined efforts to keep the vent clear of water. Continued but wavering pressure raises a ragged miniature fountain 2 to 4 feet upward, and internal beady jets are exploded up to 10 feet. With no apparent regularity the show stops for a few seconds and the water level in the tube drops 2 feet or so below the surface where it fluctuates momentarily before the next eruptive bursts begin. Southwest from Feisty Geyser are several small spouters which are more or less continuously active.

About 50 feet north from this geyser a ragged cleft in the sinter approximately 6 by 12 feet in size contains water at a temperature of 199.4° F, in a state of strong agitation about 2 feet below

the surface and also back in under the broken ledge on the north side. In a similar but smaller cleft close by on the south boiling can be heard, and washing in the gravelly sinter around each of these vents indicates filling to the point of overflow on some occasions. Deposits of an indigo-blue material in spots on the sinter around the west end of each of these features have been determined to be the mineral,

25. OPAL SPRINGS are a proximately 250 feet north of the northern end of Nuphar Lake on the high ground forming the eastern rim of Porcelain Basin and about 350 feet northeast of Blue Geyser.

The name Opal was used by Peale in 1878 in referring to a single spring or pool located in this area which he said "has bluish water, which flows from the spring over ochre-yellow terraces." Hague's atlas groups several springs in the same general area under the name of Opal Springs. This is accepted, and may now be considered as pertaining to at least one rather large pool and at least two different groups of closely assembled high temperature steam vents and two predominantly water vents. All are closely related to Porcelain Terrace, which falls immediately away from this area toward the southwest and is being built up from mineral matter supplied by water from these thermal features.

Each of the steam groups includes several orifices directed in diverse directions from a hood-like mound of yellow-tinged gleaming opal-like sinter which has been deposited by the vents themselves. The deep brown of iron oxide adorns the smooth well-rounded rim of each orifice and blends outward to ochre-yellow. These mounds are of

relatively recent origin, it being well known to me that they have developed to present size since 1935. Sinter deposition within each orifice appears to be rather rapid. The temperature of the steam at each of these groups of steam vents in the fall of 1952 was 197° F.

In addition to the steam vents mentioned, there are several comparatively large vents which emit hot water and a large number of small holes and cracks from which both water and steam, or one or the other is ejected. Single and multiple cone-like formations in a variety of sizes are numerous, some with well-developed miniature terraces which merge with similar ones close by and below with those of the Porcelain Terrace. Runoff water from some of the larger vents is carried away by strikingly neat and exquisitely formed channels in the porcelain-like sinter. The temperature of the water in the vent nearest the road was 199.4° F. in the fall of 1952.

26. PORCELAIN TERRACE is the name given by a Superintendent's committee in 1927 to the dense sinter formation which clothes the slope rising around the eastern side of Porcelain Basin. Here a shallow film of water flowing from the Opal Springs area above cascades downward over and builds up countless miniature terraces of faintly yellow-tinged sinter which resembles porcelain in appearance.

27. GROWLER SPRING is approximately 450 feet slightly west of north from the northern end of Nuphar Lake and 200 feet beyond the Opal Springs area below the edge of the highly altered rhyolite slope

which rises above Porcelain Basin along its northeastern side.

Some of Hague's writing in 1887 vaguely indicates that this spring may have then been a geyser, but at this location his atlas shows no named feature. The one here considered received its present accepted name from a Superintendent's committee in 1927.

The squarish puddle of yellow-tinged water which is about 10 feet across is located in a ragged basin about 13 by 18 feet in size among highly altered rhyolite boulders and gravel. The crumbly slope rises about 15 feet above the pool on the northeastern side. The surface of the water is in an almost constant condition of rather violent splashing, and it appears that the level changes sufficiently at times to result in slight overflow. Sulfur is being deposited upon the rocks around the edge of the pool, and the yellow color of the water suggests that this mineral is being held in suspension by it. The temperature of the water in the fall of 1952 was 195.8° F.

28. NUPHAR LAKE is about 800 feet east of Valentine Geyser and on the southeastern side of the highway.

The name was given by the Hague Party in 1904 in recognition of the yellow water lily, Nuphar, which thrives on its surface.

It is a body of water about 600 feet long from north to south by nearly 200 feet in width, fed by springs located at its southern end. Its greenish-blue water is clear and seems unaffected by the thermal vents near it.

Park Ranger Naturalist David Beal was collecting aquatic

insects from the waters of this lake in 1952 and noted the presence of several warm vents in the shallow water along the eastern margin.

29. SIEVE LAKE is about 1100 feet north of Valentine Geyser and shortly beyond the western edge of Porcelain Basin in a large flat depression.

This feature was called "Turbid Lake" by Peale in 1878, but apparently Hague, having observed many holes in its bottom from which gas escaped, decided Sieve Lake was a more appropriate name.

Lying in a drainage basin it receives surface runoff water from all directions, and thus varies seasonally considerably in both size and shape. When at maximum level it is about 600 feet long from east to west by about 100 feet wide, and during this stage there is an appreciable overflow through the low gap into Porcelain Basin. Irregularly funnel-shaped holes of various sizes in the silt bottom are conspicuous from which gas bubbles are infrequently discharged to rise lazily through the shallow, greenish, turbid water. The temperature of Sieve Lake in late October 1952 was 68° F.

30. STEAMVALVE SPRING is about 225 feet northeast of Emerald Spring and about 150 feet southeast of the Norris Museum in the middle of the parking area adjacent to the rest room.

During the Hague Party's work in 1904 it must have been a conspicuous and noisily active steam vent, as it received sufficient attention then to be given the name it now bears and be placed on

their map. It seems, however, that it may have become much less active, perhaps even appeared completely dormant, by the time the Norris museum and service roads to it were being built in 1930. At this time the area was graded over and Steamvalve Spring slept beneath an overburden of gravel and black top paving.

Sixteen years later Park Naturalist David de L. Condon wrote in part as follows in Yellowstone Nature Notes: "On May 22, ---about 9:30 a.m., Mrs. L. F. Albinger noticed a small crack form near the center of the parking area, with steam and water starting to come out of it. The volume of water increased and began to well up through the crack and run down the roadway---. A burst of steam broke loose a small section of the parking area and the churning action of the steam bursts --- began mixing the loose surface material with the water, and within about ten minutes a small crater about 1 x 2 feet was splashing out muddy water, and the violent, turbulent action was rapidly enlarging the newly formed vent. About 10:00 a.m. I drove into the parking area, accompanied by Park Naturalist Harold J. Brodrick ---. The Albingers told us of the initial action. ---We periodically returned --- from our work at the museum and made pictures of it as well as observations of its activity. --- by about 4:00 p.m. --- it had increased in size to nearly 8 x 9 feet in diameter and approaching 5 feet in depth. ---On the 23rd --- 24 hours after the initial action --- the crater had a diameter of about 12 feet, was about 4 feet down to the water surface ---." During the succeeding thirty days the crater enlarged to 18 by 15 feet and was

alternately almost dry then nearly full of violently boiling muddy water, often splashing upward 3 or more feet. This activity maintained through the 1946 season, and it became necessary to construct a guard rail around the crater. Careful checking of Hague's map leaves little doubt but what this is the rejuvenated Steamvalve Spring.

By the summer of 1947, Steamvalve having blown its way to freedom seemed again content to lie almost inactive. Light steaming from the bottom of the 4-foot crater, however, should be sufficient warning for mere man not to endeavor to close one of nature's safety valves again.

31. DOCTOR ALLENS PAINT POTS are approximately 350 feet southeast of Emerald Spring and 650 feet northeast of Monarch Geyser Crater.

The name was suggested by a Superintendent's committee in 1927, the reference apparently being to Dr. E. T. Allen who, it is rumored, sustained some minor burns while working in this area during his association with Dr. A. L. Day on their extensive investigation of Yellowstone thermal areas in the 1930s.

In this area on the gentle barren slope of clay and rhyolite gravel an atmosphere of utter devastation prevails, and the insecure crusty nature of the ground surface demands extreme caution from those venturing upon it to prevent serious burns. Sulfurous fumaroles, steam jets, miniature and sizeable mud and paint pots, and several puddles of turbid hot water are scattered indiscriminately over an area about 150 feet in length by 100 feet wide. Although nothing of

especially arresting importance appears to be taking place here in general, interesting and colorful activity was reported in 1950 by Park Ranger Naturalist Beal, who noted an "orange-red" "spouter in the center of the basin" on August 2nd which remained active for a month and then became less active and turned gray in color. The same vent was "very active and very red" again on September 10th, perhaps due "to the heavy rains of the preceeding day replenishing its water supply."

32. STEAMBOAT GEYSER is about 950 feet south of the Norris Museum and 600 feet southeast of Monarch Geyser Crater.

The birth of this geyser is described by P. W. Norris in his report of 1879 as follows: "The new crater which burst forth in the Norris Geyser Plateau, with such upturning and hurling of rocks and trees, August 11, 1878, and was for the remainder of last year a high crater of hissing gas, steam, and mud, seems this year to have settled down to business as a very powerful flowing geyser, having, in common with many others, a double period of eruption, one some 30 feet high about each half hour, and another of nearly 100 feet and long continued, each 6 or 7 days, and is doubtless still changing." Peale recognized the youth of this feature when he observed in 1878: "It consisted of two roaring steam-holes on the side of the hill, that look as though they had just burst through the surface. ---There is no deposit marking the opening, although stones surrounding the hole are beginning to have points of geyserite deposited on their surfaces.---." Peale called it the "Steamboat vent", as, having not

seen it in eruption during his brief stay in the area he further stated: "Whether it is now a geyser with regular periodical eruptions I cannot determine---." During much of the period, however, since the time of Norris and Peale this feature has displayed geyser activity, and in 1927 was named "New Crater Geyser" by a Superintendent's committee. This name was used for about 10 years before being changed to the approved name Steamboat Geyser.

It lies in a large basin eroded into the weathered rhyolite hillside by the action of the water thrown from its own vent. This basin is about 75 feet long by 20 feet wide at the northwest end and 50 feet at the southeast end; at this point the floor rises toward the east to merge with a ten-foot, very irregular escarpment of weathered, varicolored rhyolite around the northeast side.

Steamboat's vent is a highly irregular, boulder-choked fissure about 25 feet long northwest to southeast and an average of 3 feet in width. At the surface it is a double vent; the northwestern opening, about 9 feet long, is separated from the 6-foot southeastern one by an 8-foot bridge of weathered rhyolite spanning the surface fissure 2 to 4 feet below the general level of the ground. During the most powerful eruptions the subterranean blast of water is split by this bridge and emerges with a double-barreled effect as two separate highly disseminated masses ejected in opposite directions accompanied by the roar of escaping steam and swish and splatter of angry water. The double-barreled eruptions seem to occur at irregular intervals and virtually all of the water expelled by the northern vent is directed back into it by the sloping walls of the surrounding basin. Angular computations showed that jets of water from the

northwest vent were thrown a vertical distance of 35 feet into the air, while those from the southern vent reached 16 feet.

More common are eruptions from the southern of the two vents, with water only rushing and gushing below the surface in the larger northern opening. On these occasions, which seem to occur on intervals of from 1 to 3 minutes, a very considerable quantity of water is thrown in a wild, ragged mass to the far side of the yellowish sinter-lined overflow channel. Much of it drains down the steep slope toward the south but as much or more, perhaps, pours back into the belching vent.

It is evident that throughout the past there has consistently been more activity from the southern opening, as in this vicinity deposition of brownish, spongy-appearing sinter is much more in evidence in the drainage channel and on the rhyolite boulders littering the erosional basin. The growth of yellow colored algae is considerable in the runoff channel, and the pine trees at the edge of the forest, subjected to countless steam and mist baths and the resultant heavy icing in winter, are badly stunted.

33. CISTERN SPRING is in the timber near the base of the slope about 250 feet southwest of Steamboat Geyser and about 500 feet northwest of Echinus Geyser.

Although it appears that a thermal feature has been active here for a long time, neither Peale nor Hague recognized one at this location. The name was accepted by a Superintendent's committee in 1953.

The basin of this spring is irregularly circular and about 15 feet across. An inconspicuous rim of very dense dark gray sinter

rises rather abruptly 2 to 5 inches above the surface of the water around the western margin of the basin, and at the water's edge is delineated by an irregular thin band of black deposition which in some places clothes distinctly knobby and in others fine needles of sinter. This rim rounds outward and downward to merge with the gravelly surface surrounding the basin, and through a ragged opening on the south side there is very meager overflow. Sulfur deposition reaching from the water's edge downward into the basin is present around that portion of the basin bounded by the low rim; the depth-extent of this deposition is obscured by the turbidity of the water.

The character of the water and action of the spring are somewhat variable. Dark gray water in a state of rather strong ebulition, especially above an extensive area off center toward the southwest, seems to be most characteristic, but the feature has been observed when the water was much less turbid and only slightly agitated. Rough measurements indicate that the bottom of the basin is less than 2 feet below the water's surface around the northeastern side; it appears, however, to rapidly deepen toward the vent itself which is toward the southeastern ~~eastern~~ side. Strong currents of circulation from the centers of ebulition toward the southeastern rim are apparent. The temperature of the water in the center of agitation was 191° F. in the spring of 1954.

34. VETERAN GEYSER is about 450 feet south of Monarch Geyser Crater and about 800 feet west of Echinus Geyser in the ancient sinter formation just beyond the edge of the forest.

It appears that this geyser was named by Hague prior to 1890. In regard to it Peale in 1878 reported: "No. 52 is a deserted geyser hole with a little water at the bottom.---"

This is a rather odd feature which seems to consist of at least two related units, one being a large basin whose southern wall appears to have been pierced by an adjacent more active steam and water vent.

The basin is about 19 feet long from northwest to southeast, about 14 feet across and a maximum of 4 feet deep. Green tinged water at a temperature of about 190° F. stands 18 inches deep in the southern portion of this basin, shallowing toward the edges in all other directions. In the southern wall, lying partly above and partly below the water line, a ragged port 3 feet long by several inches wide and a 3-inch hole a foot lower down open into the adjacent vent.

There is a much more active feature with its surface opening, a 3 by 5 foot ragged eliptical hole in the ancient sinter, lying parallel to and about 3 feet south of the basin. Below this opening the vent becomes a cavernous cleft which extends northwest to southeast and laterally widens under the ledge and downward to join the ports opening into the basin on the north. Water at a temperature of 196° F. in a consistent state of violent agitation thrashes about in this cavern, and the resulting pulsing action forces some water through these ports into the adjoining reservoir. During some powerful splashes water is splashed out of the surface opening, and where it has fallen a fine display of beady sinter has formed. The water level usually is

about 2 feet below the surface. The deposit of pearly sinter at the water edge in the large basin suggests there is probably slight but perhaps rather regular fluctuation of the water level. Evidence of runoff toward the southeast from the active vent suggests that occasional violent eruptions occur.

35. CORPORAL GEYSER is about 350 feet south of Monarch Geyser Crater and about 850 feet northwest of Echinus Geyser, in the edge of the pine forest at the base of the gravelly rhyolite slope.

A feature in this location is designated simply "Corporal" in the Hague Atlas of 1904. Park Ranger Phillips referred to it as "Corporal Geyser" a periodic spring---" in 1927.

It consists essentially of a ragged crack in the gray beady sinter about 3 feet long from northwest to southeast in the shape of a dog leg. The width varies from a few inches to openings of greater size at each end, the one at the southeast being about 10 inches square. Lying below and 5 feet in front of this vent is a circular pool which receives most of the water expelled during eruptions of the geyser.

Eruptions observed were minor in size but rather wild in character, consisting of rapid surges of water from the entire length of the crack accompanied by a violent spluttering and splashing of water about 18 inches upward from the square shaped opening for a period of about 9 minutes. No regularity of interval between eruptions was observed, but they seem to take place quite often during an eruptive phase. The water thus discharged into the turbid pool below overflows into the flat sinter drainage channel and reaches Tantalus

Creek 150 feet west. The temperature of the water during eruptions is 199.4° F.

36. PALPITATOR SPRING is about 250 feet southwest of Monarch Geyser Crater and about 1100 feet northwest of Echinus Geyser, on the sinter flat.

This feature was named by Hague because of the rhythmic beats produced by bursts of steam.

The pool of this spring lies in a very flat shallow basin about seven feet across, around the north, west and south sides of which pebbly sinter of normal color is conspicuous. The vent consists of two rather small ragged clefts located west of center in the basin, above which the clear water at a temperature of 178° F. is kept in a continuous state of palpitation by gentle bursts of gas at depth. This agitation sets up small concentric waves which wash the margin of the basin and cause a light but steady overflow toward the southwest. Indications of meager overflow all around the edges suggest that on some occasions the water level rises appreciably. Brownish green algae is present at the water's edge on the east side of the pool and along both sides of the runoff channel.

37. SPINY PEBBLE SPRING is approximately 175 feet southwest of Monarch Geyser Crater and approximately 1050 feet northwest of Echinus Geyser; it is about 75 feet east of Palpitator Spring and about 25 feet from the fringe of trees.

The name suggested by the presence of many spiny pebbles in the basin of the spring was accepted by a Superintendent's committee in 1953.

The basin of the pool formed by this spring is almost perfectly round, about 11 feet across, rather shallow, with a bottom which slopes gently toward the ten-inch pipe-like vent located about in the center. Large numbers of pebbles ranging in size up to an inch in diameter clothed in a gray sinter formation of delicate and exquisitely formed spines to resemble miniature hedgehogs adorn the bottom of the basin. Overflow by way of a shallow channel toward the southwest results in formation of another shallow puddle of similar size on the gravelly sinter immediately adjacent. Apparently the water level fluctuates some 6 to 8 inches below the rim for extended periods on some occasions, as the pebbles here in a band 3 to 6 inches wide on the bottom of the basin have become lightly colored with a deposition of sulfur. Intermittent filling to the point of minor overflow followed by draining of the basin takes place, but the frequency of this cycle is not known. The temperature of the water in this spring was 127° F. in the fall of 1952.

38. FEARLESS GEYSER is about 150 feet southwest of Monarch Geyser Crater and about 1100 feet northwest of Echinus Geyser, on the sinter flat.

This feature apparently was named by Hague's geological party in 1883, as it was referred to by that name when they took a

water sample for analysis and recorded a temperature of 197.6° F.

The pool of this spring is in a nearly round basin about 14 feet long from east to west and 11 feet across. The outer portion of this basin is gently flared and dark gray with a fine filamentous deposition of sinter, beyond which the walls of the well drop away steeply into the dark ominous-appearing, funnel-shaped vent. Because of undulations in the surrounding sinter surface, the water level varies from 3 to 6 inches below the edge of the basin. The flare of the basin floor in a band from 3 inches to about a foot in width above the water is colored with a mass of dark-colored sinter-encrusted pebbles bristling with very fine needles which give to each the appearance of a miniature hedgehog. The inner portion of the pit or well is yellow-green to dark green-blue in color.

During my periods of observation no eruptions of this "geyser" were noted, and available records irregularly report but very minor activity of this nature. The band of spiny pebbles present in the basin suggests perhaps periodic fluctuation in the water level. My observations only record a continuous bubbling of the clear 190° F. water above the vent; there is no evidence of overflow from the pool.

39. MONARCH GEYSER CRATER is 800 feet southwest of the Norris Museum; 500 feet southwest of Emerald Pool.

The name "Monarch" appears to have been given to a geyser in this location by P. W. Norris; in his 1884 guide book he said:

"---The Monarch---daily throws one vertical and two diagonal columns of hot water about 100 feet high, with rumblings which shake the valley, until a creek of hot water for a time bars all travel upon the highway." There is some confusion here, however, as Peale did not recognize a major feature in this location in 1878. It seems highly probable, however, that it may be the same as his No. 73 which he called the "New Geyser" and that he may have mislocated it on his map.[7] (His brief description of this feature coincides closely with Hague's of the "Monarch", which is in the same location as the present day Monarch Geyser Crater and whose description in 1885 remains reasonably applicable today.[7]) Peale did not witness any eruptions from the "New Geyser" but stated: "---the character of the surroundings present proof that there are eruptions but we did not witness any." Hague, on the other hand, spoke of "---the geyser playing every 4 hours" and further mentioned "---the natural displays, which throw a column of water 50 feet into the air." An unconfirmed reference indicates that there may have been an eruption as late as 1913. Peale believed that this feature was of recent origin and the dearth of recorded eruptions indicates that it may not have survived as a geyser much more than 30 years. Thus, it is now recognized as Monarch Geyser Crater and not as an active geyser.

The crater is a large alcove-like three sided basin eroded out of the rhyolite of the steep pine covered hillside. It is oriented with its open side toward the northwest. It is about 135 feet long from northwest to southeast by 80 feet across and the

gravelly wall of disintegrated rhyolite rises steeply some 35 feet around the southeast end before merging with the slope above.

Two ragged, parallel clefts in the rhyolite trend northwest to southeast; they were once active as geysers and now lie submerged in gray green water which forms a pool in the floor of the crater about 55 feet long by 28 feet wide. The crater is deep and ominous in appearance above the vents but is shallow with a sulfur-colored silt bottom around the eastern side. Each of the clefts is about 16 feet long and of irregular width from 1 to 4 feet; between them a hump of rhyolite stands from 2 to 4 feet above the water surface.

The water in the most northerly fissure is continuously bubbling with vigor at a temperature of 190° F. Only an occasional bubble breaks the surface above the other vent. Several highly altered, scaly, multicolored boulders of rhyolite lie on the floor of the crater and lodgepole pine trees up to 12 feet in height growing among them testify to the absence of geyser activity during a long period. A small stream of warm water flows from this crater toward the northwest to join the overflow from Emerald Spring and Minute Geyser bound for Tantalus Creek.

40. MINUTE GEYSER is about 250 feet northwest of the crater of the Monarch Geyser and 700 feet southwest of the Norris Museum on the level of the southern portion of the Norris Geyser Basin.

Doctor A. C. Peale writing in 1878 accepted this name saying: "This geyser, which is located close to the wagon road on the right as

it begins the ascent of the hill, was named by Mr. Norris." Actually, Norris' reports of 1878 and prior years do not include this name but in his guide book of 1884 he mentioned the "Minute Man Geyser" and not Minute Geyser. The name Minute Man Geyser is approved for a feature in the Shoshone Geyser Basin, but nevertheless, though in error, it was also used in reference to the geyser at Norris until very recent years, even though the name Minute Geyser had been accepted by a Superintendent's committee in 1927. Peale, on the basis of his observations of five consecutive eruptions with intervals between varying from one minute and ten seconds to one minute and 55 seconds and duration of from 10 seconds to 2 minutes, stated that: "Judging from these few observations the geyser has been very well named. The water is thrown to a height of thirty to forty feet." In his mind the word minute obviously had reference to a period of time but in the minds of some more recent investigators it has been interpreted as having reference to the size of the geyser. Fragmentary reports and casual observations of this geyser's major eruptions since that time justify Peale's early conclusions, as eruptions variously reported from 20 to 60 feet in height cannot be regarded as minute, meaning small. Some reporters having watched the frequent eruptions of the small associated vent may have considered it adequate reason for use of the term minute, meaning small, but if so they were not observing the real Minute Geyser in action.

The Minute Geyser system includes at least three vents, two of which are located on a low, gray, flat mound of dense sinter, quite

irregular in shape but roughly 32 feet across from northwest to southeast by 20 feet in the opposite directions. The other is a sizeable pool which lies a few feet to the southeast off this sinter mound. The sinter mound merges with the gravelly rhyolite wash from the hillside on the northeast.

What perhaps should be considered the major of the two main vents lies in a trough-like depression in the sinter mound, which is about 9 feet long from southeast to northwest, about 2 feet deep and from 2 to 3 feet wide. The actual vent is an irregularly funnel-shaped opening about 12 by 15 inches across located at the southeast end of this trough. The second vent, located 7 feet to the south, is simply a rather ragged roughly circular hole in the sinter about 2 feet by 18 inches in size.

Records which give a clear picture of this geyser's overall activity are lacking but casual reports seem conclusive in that they do indicate at least more than one type of eruption from this system. Efforts to actually observe these and establish their relationship during the fall of 1952 were not wholly successful.

Many eruptions from the southern vent on the mound were observed. Heavy boiling just below the sinter surface initiates the actual eruption, which straightway follows in the form of spurts and violent splashing from the vent to heights of from 6 inches to 3 feet above the sinter. Fifteen consecutive eruptions of this kind were observed with intervals between varying from 7 to 13 minutes, average 10 minutes. The eruptive activity remained strong throughout,

waning only during the latter 30 seconds of play, after which the water level dropped in the vent about 18 inches with much noisy bubbling. During this activity there is meager overflow toward the southwest and a fair-sized stream pours into the trough, partially but never completely filling it; underground circulation into the erupting vent is indicated. The temperature prior to eruption was 196° F. and during eruption was 199° F.

Later in the fall I arrived in time to watch the trough vent of the Minute Geyser during the last few minutes of an eruption. In this period many closely spaced, ragged and very explosive jets were observed, the interval between varying from 20 to 60 seconds. Others have estimated these jets to reach heights varying from 20 up to 60 feet. On this occasion angular measurements showed the top beads reaching a height of 24 feet but it is presumed that greater heights may be attained during the earlier stages of the eruption. Bursts such as these are probably similar to those observed by Peale, on the basis of which he concurred with Norris in the propriety of the name Minute Geyser.

Observations following this eruption revealed that the pool to the southeast had been drained to a very low level and steaming was heavy under the ledge projecting above it on the northwest side.

It appears that this geyser may stage one or more such eruptive phases in the course of a 24 hour period, during which explosive bursts follow one another in rapid succession. Some records of the past indicate that such phases have occurred on an interval as

short as 3 hours and endured for more than an hour. More recent but inconclusive records, however, indicate eruptive phases occurring at considerably longer intervals and lasting for a shorter period. Between these phases almost continuous eruption from the associated vent, such as described above, has been observed. Whether or not this is a uniform occurrence or whether there is a definite cyclic relationship between the two vents is not definitely known.

41. EMERALD SPRING is about 500 feet northeast of Monarch Geyser Crater at the brow of the hill 300 feet southwest of the Norris Museum.

In 1878 Peale apparently unintentionally named this feature when he said: "No. 5, emerald pool, is somewhat concealed in the timber, and is a handsome, yellowish emerald-tinted pool measuring 40 by 50 feet. The basin is sulfur lined and has a gray border. The water boils at one end, and has a temperature of 186° F. on the edge of the spring. There is a considerable overflow, which goes to the southwest." Norris recognized the name in 1881 when he said: "Emerald.- Evidently has an occasional eruption, although none were observed."

This spring lies in a gravelly rhyolite flat at the head of its own drainage, which drops away sharply toward the southwest. The pine forest crowds it closely on the east and west and a weathered bank of gravel rises along the northeast side. Its water, which is beautiful yellow-green to dark green, occupies an elongated basin measuring 46 feet in length from northwest to southeast by 32 feet in width; the rim is quite irregular in outline, low and sinter

covered. From the rim a bouldery flat ledge extends inward from 1 to 10 feet before dropping about 4 feet to the main basin. This level in turn drops away to the main vent which seems to lie along the northeast side and extend toward the southeast end. Sulfur deposition is rather heavy on the flat ledge under the water and the red of iron rust is prominent along the edge of the embayment on the east and northeast sides. Many old logs and sticks have become embedded in the sinter toward the western end of the pool.

In general reports about Emerald Spring indicate substantially the same type of activity as that observed by Peale, that is, gentle but consistent boiling at several points on the surface and somewhat more vigorous ebullition in the narrow neck at the southeast end, resulting in appreciable and consistent overflow. There have, however, been occasions when this spring has departed far from this mild manner to become violently and spectacularly active as a geyser. In the early 1930s several such periods of eruptive activity were reported, those of 1932 being, perhaps, among its most spectacular displays. Many of these I witnessed. In regard to this series of eruptions Park Ranger Naturalist Arthur Nash wrote: "On July of this year it (Emerald Spring) again resumed its geyser activities throwing water to a height of from 20 to 25 feet. It continued these eruptions at intervals of 35 minutes." Years later, in 1948, Park Ranger Naturalist Sanborn reported in a similar vein that: "The other pool of interest has been Emerald Spring which erupted in July and drained down over a foot and a half." Between the mild and maniacal periods, it is known also that often much of the surface of the pool boils

violently, frequently becomes noticeably murky and that minor eruptions occur which discharge considerable water.

Such variety of action no doubt results in considerable variation in temperature of the water but that recorded in the fall of 1952, 194° F. was only one degree above a recording made just a year earlier.

42. BATHTUB SPRING is about 350 feet southwest of Valentine Geyser on the gravelly slope about 90 feet due west of the Norris Museum.

This feature was so named by a Superintendent's committee in 1927 because its shape resembles that of a bathtub. In 1884 Hague referred to this spring as "Schlaumkessel", a German term meaning mud kettle, and it so appears in his atlas of 1904. In those days it must have been more of a mud pot than now.

It is an ear-shaped pool about 14 feet long from northwest to southeast by about 8 feet wide, lying in a flat depression on the side of the slope. The irregular cobbly rim covered with pebbly sinter rises to 8 inches around the southeast end but is very low at the opposite end. The clay and obsidian sand slope of the hill rises about 10 feet quite sharply above the southeastern end.

The water in the pool is murky gray in color and its surface is broken by quiet ebullition in two places. Consistent but very meager overflow occurs at the northwest end, except during periods of greater activity when minor eruptions take place and augment the over-

flow appreciably. The temperature of the water is 194° F. In 1884 Hague's party recorded a water temperature of 195.8° F.

A smaller also ear-shaped pool occupying a ragged hole in the sinter lies about 8 feet northwest of the Bathtub. It is about 5 feet long from north to south by 1 to 2 feet in width. Its murky gray water is in a consistent state of ebullition at a temperature of 196° F. and overflow toward the northwest is slight but continuous. Unofficially this feature has been called "Bathtublet".

43. HARDING STEAM VENT is well surrounded by timber in a dry gully less than 100 feet east of the Norris Museum.

A thermal feature at this location prior to 1923 was known as "Tippecanoe" geyser, but according to Park Ranger Phillips' account in the Ranger Naturalist Manual of 1928 it was "renamed Harding Geyser as it became unusually active just before the visit of President Harding in 1923." Until now Harding Geyser has been the accepted name of this unimportant feature. However, since no written account or verbal statement is available to substantiate geyser action at this location, the revised and more appropriate name here used was accepted by a Superintendent's committee in 1953.

The active vent of this feature is a very irregular cleft about 4 feet long, from north to south, by from 4 to 10 inches wide, located among sinter-encrusted somewhat iron-stained cobbles and boulders of rhyolite at the bottom of a ragged pit approximately 5 feet deep. Emission of great quantities of steam is the only action one readily sees here; closer examination, when possible through the

clouds of vapor, reveals water fluctuating at approximately the 4 foot level, and the sound of water seething and boiling in an extreme state of agitation is continuous. The temperature in the vent at a location approximating the water level was 198° F.

44. BLACK PIT SPRING is approximately 70 feet due north of the vent of Echinus Geyser; it is less than half this distance from the high gravelly rim on the north side of this geyser.

It is a relatively new feature which until recently was unnamed. Park Ranger Naturalist Douglas' report of June 1939, alludes to it as follows: "A steam vent has broken out on the hillside between Vermilion Spring and Echinus Geyser. The roaring of the steam can be heard several hundred yards." (See Vermilion Spring for its new location) A Superintendent's committee in 1953 accepted the name here used.

The elliptical basin of this spring, which is 8 feet across by 11 feet in length from north to south, has been excavated in the rhyolite gravel slope by the spring's action since 1939. The time required for the change from a "Steam vent" to its present status is not apparent from observers' reports, but it is known to have been in about its present state of activity for many years. The gray border around the pit-like basin grades toward the center into deep black as the steep conical bottom merges in the obscure depths with the vent itself. Behind the basin the steep gravelly bank rises 4 or 5 feet to merge with the slope of the hillside. The strong and continuous agitation of the surface, which bubbles and splashes upward a

foot or more, apparently is in response to gaseous pressure at depth and not boiling water, as the temperature here is only 190° F. The bursting of gas bubbles in the subterranean plumbing of the feature is audible. Obsidian sand is much in evidence around the western side of the basin, and overflow in this direction into the channel below Echinus Geyser is very meager.

45. ECHINUS GEYSER is about 1400 feet almost due south of the Norris Museum and 1000 feet southeast of the Monarch Geyser Crater.

Echinus was so named by Peale in 1878 "because the pebbles around the basin have some resemblance to the spine-covered sea urchin".

This geyser nestles in a neatly curved niche above which the gravelly wall of altered rhyolite rises sharply 3 to 10 feet before flaring more gently to merge with the sparsely forested slopes on the northeastern and southeastern sides. The main pool is about 40 feet across from northwest to southeast by about 50 feet in the opposite directions. A rough sinter-covered extension another 80 feet toward the northwest upon which the water lies in shallow depths when the vent is at the maximum overflow stage gives the impression of a much larger pool. This extension ultimately breaks up into two small channels which drain into the main runoff toward the northwest to join a branch of Tantalus Creek. The surface well of this geyser is a pit about 20 feet across and roughly circular, which drops very irregularly among a mass of rhyolite slabs and boulders which have slumped into it. All surfaces which are covered by water during quiescent periods are

encrusted with sinter, much of it highly spiny in character and all colored dark red, about which Doctors Allen and Day say this: "It contains more than 50 per cent of ferric oxide, 6 percent of oxide of aluminum, 20 percent of silica, and 5 percent of arsenic pentoxide." In channels recently cut by the apparent rejuvenation of strong geyser activity which has removed this red deposit, normal gray to white sinter is found and in it wood fragments, needles and cones long buried are brought to light.

It may be that Echinus has been inactive as a geyser for many years, or it may be that because of its distance from the Norris Museum seasonal observers have not been present to witness its eruptions. At any rate reports of actually witnessed eruptions of this geyser are completely lacking from 1878 until 1948. In the intervening period such reports as: "slight boiling", "much boiling and steam", "no eruptions, much boiling and evolution of steam" and "no indicated eruption" are characteristic.

The present highly active phase of this geyser apparently had its beginning after the 1947 season, at which time no eruptions were reported; just when is not evident, perhaps during the following winter or early spring. At any rate by the summer of 1948 it had established an eruptive regime which moved Park Ranger Naturalist Sanborn to say that Echinus Geyser "---has been the most regular of the four large geysers in this basin. It has been erupting to a height of from 10 to 80 feet every hour and a quarter during the season.

Men stationed at Norris during the 1952 and 1953 seasons

reported eruptions from Echinus on an average interval of 3 hours with durations of from 3 to 5 minutes and heights from 50 to 65 feet.

During observations in the fall of 1952 several eruptions were observed at a distance and one at close range. On this occasion the pool was almost full of beautiful greenish water upon my arrival and filling was completed within a few minutes. Soon thereafter rather heavy bubbling was noted along the south side followed within a few minutes by violent agitation over the entire surface of the pool; very quickly thereafter the entire surface of the pool seemed to rise up and with explosive violence break into a magnificent fountain-type eruption. The main mass of water appeared to be in explosive agitation to a height of from 15 to 25 feet and above this ragged jets were propelled to considerably greater heights. On this occasion these jets were measured by angle computations to a height of 32 feet but other observers believe that some reach a considerably greater height. This eruption lasted 4 and one-half minutes, which is about average for all reports during the past four years. The temperature was 189° F. just prior to the eruption and the same 2 minutes afterwards, at which time the water level in the crater was about 4 feet below the surface. Hague's party while collecting a water sample in 1884 recorded 195.8° F. for Echinus. One half hour after the eruption the level had raised about two feet and gradual filling continued. Park Ranger Naturalist David Beal believed that during the 1951 and 1952 seasons an eruption could be counted upon

"within 15 minutes of the time the overflow from the crater reached the end of the terraces built up on the northwest side of the geyser".

46. ARCH STEAM VENT is a short distance above the general level of the basin floor on the steep timbered slope about 500 feet south of Steamboat Geyser and about 200 feet southwest of Echinus Geyser.

The name, suggested by the appearance of the feature, was accepted by a Superintendent's committee in 1953.

There are indications that this vent is active at or near the location of an older thermal feature of some kind, but neither Peale nor Hague recognized one at this location. The mound-like structure and the adjacent slope area toward the north are clothed in dense black sinter which appears to be indicative of much older thermal activity.

Collapse of the mound in two places and subsequent erosive action have left intact a thin arch about 2 feet wide standing some 3 feet or so above the now active vent, which is a ragged cleft among the rhyolite boulders about 5 feet long from north to south. Toward the north on the downhill side of the mound a very irregular cavern 4 to 5 feet in diameter has been created which narrows southward beneath the arch to merge beyond with another smaller ragged hole opening to the surface. The noisy ejection of steam from the vent produces billowing clouds of vapor, and occasional showers of water droplets blasted outward drench the interior of the crater and area close by. Alteration in the rhyolite crater has been considerable,

resulting in colorful displays of red and brown iron oxide, and light deposition of sinter is apparent on some of the boulders. Temperatures varying from 192° F. to 198° F. were recorded in the vent.

47. PEBBLE GEYSER CONE is about 600 feet north of Green Dragon Spring and about 800 feet south of Monarch Geyser Crater.

This feature is No. 55 on Peale's map of 1878, in regard to which he said among other things: "This, as far as we could determine, is one of the most important geysers in the basin.---Its name was given to it from the abundance of rosetted pebbles in the basin outside of the tube. On the 14th (of September) we saw from a distance two eruptions of this geyser, which we estimated to reach a height of 50 feet. The interval between them was one hour and fifteen minutes. They lasted a few minutes only." Apparently it has long been inactive as a geyser and is thus now known only for its cone.

The vent is about 2 feet long by an average of 10 inches in width, located on a flat, much fractured, platform-like cone structure of very dense, gray, cobbly sinter in the surface of which are many small irregular pebble-filled basins. This platform stands from 3 to 10 inches above the general level of the sinter mound, and is about 9 feet long from northeast to southwest by 5 feet across. Close by the lip of the vent on the southwest lies a remnant of wood about 2 feet long which is now highly impregnated with silica and in places encased in sinter as much as 4 inches in thickness. A similar

but smaller remnant lies near the vent on the northwest side. An ancient but well defined runoff channel drops gently away from the cone toward the northeast, and a stunted but obviously old lodgepole tree about 3 paces southwest of the cone attests to the long period since the last eruption from this vent, which now only steams quietly and gurgles water at depth. A large slab of sinter visible in the throat of the vent suggests that vandals of the past are most likely responsible for the death of this onetime "important" geyser.

On the eastern edge of this same shelly sinter mound, about 22 feet northeast of Pebble Geyser Cone, another long inactive cone is located, which is roughly circular, about 4 feet across at the base and 2 at the top within which sinter gravel has been deposited to within 10 inches of the rim. The only sign of thermal life apparent when this investigation started was considerable heat in the gravel within the basin. Since the rim of the cone stands above the general level of the mound, it seemed probable that the gravel load within had likely been placed there by human hands, and that removal of it might possibly result in rebirth of thermal activity.

The character of the material subsequently removed from the vent left no room for doubt but that it had been deliberately placed there. The first 4 inches of sinter gravel and small stones were compacted but not cemented. From there downward for about 8 inches the material was similar in general character but included somewhat more stones and coarse pebbly material, all of which was rather firmly bound together with rather pure sulfur in both crystal and amorphous form. This material had to be broken into chunks for

removal, all of which were from 2 to 4 inches in thickness. Downward the load continued similar in general character and was not especially compacted. At a depth of about 4 feet the symetrically conical pitch of the walls reduced the vent to less than a foot across, and approximately here a slab of sinter about 3 inches thick and a foot square was found standing on edge with one corner downward into the constricted opening. Removal of this slab and the gravel and stones packed on either side of it left the vent more or less clear into some kind of chamber in which water at a temperature of 198° F. was in a vigorous state of agitation and from which blistering steam rose in large volume.

Was this feature's natural action unalterably changed by the load of debris placed in it by vandals? Could be, and inability to remove all of it could only result in failure to restore the original activity.

48. CORAL SPRING is approximately 525 feet north of Green Dragon Spring and about 900 feet southwest of Monarch Geyser Crater.

This thermal feature received its name at least as early as 1884. In that year on August 20th a geological party under the direction of Arnold Hague collected water from "Coral Spring---Norris Geyser Basin". In the 1904 atlas it is shown simply as "Coral", and it appears that the action of a 1927 Superintendent's committee in accepting the name "Coral Geyser" was ill advised, as evidence of geyser action has not been found. With this in mind, the Superintendent's committee in 1953 accepted the name Coral Spring.

Its location is on the southwestern crest of a flat sinter mound, the feature itself being a pool of very irregular outline about 20 feet long from north to south by 10 feet across. A low inconspicuous sinter rim outlines the sinuous margin around the opal-blue slightly cloudy water, and in some instances exists as a very delicate extremely thin growth lying barely above the water surface and extending as much as 18 inches inward. Below the surface a reddish-brown variety of sinter is being built outward from the walls forming a delicately spiny, fibrous to ropy appearing shelf. An interesting siliceous box-work formation crested with sinter needles is especially apparent on the eastern margin of the pool. The early analyses of water from this spring revealed an unusually high content of silica which Hague believed "deposit (it) on cooling of the waters", separation of which he further believed was influenced by "the nature and amount of alkaline chlorides and carbonates present---."

The opal color of the water and truly remarkable delicate sinter formations render this spring one of the most beautiful in the entire Norris Geyser Basin, and the presence of the exquisite and extremely fragile marginal sinter deposits seem to preclude any possibility of eruptions during a long period of the past. Its activity now consists of gentle ebullition at the southern end of the pool accompanied by rather continuous gurgling sounds and occasional very noticeable thumps which jar the formation as bubbles of gas explode below the surface. Occasional pulsing of the surface occurs resulting in periodic meager overflow at several points around the edge of the basin. Hague's party recorded 163.4° F. as the

temperature of this spring in 1884; in 1952 it was 125.6° F.

49. DOUBLE BULGER is approximately 650 feet almost due north of Green Dragon Spring and 800 feet slightly west of south from Monarch Geyser Crater, about half way between Pearl Geyser and Coral Spring.

Peale recognized this as a double feature stating: "Two bulging springs with rims and pool back of them. Below is a large pond." The name is approved, but the feature or features appear to be of less significance now than in Peale's time. Hague's map does not show them, and it is not certain that the description used here relates to the same features mentioned by Peale, though the location is close.

At this time only one spring is active in this location. Close by is a conspicuous dormant vent, and it may be that another of similar character covered with gravel is present somewhere nearby. The active spring, which could be the "pool" mentioned by Peale, is contained within the steep walls of an irregularly circular vent about 3 feet across. The gray murky water is usually in a state of violent agitation about a foot below ground level, and some water splashes beyond the rim to wet the dense gray sinter for a distance of a foot or more. Bulging and spalling off in some places of what looks like an older layer of sinter suggests rejuvenated activity at this spring. The temperature of water in the active spring was 190.4° F. in 1952.

Toward the northeast about 10 feet a funnel-shaped crater

about 10 inches across now lies dormant and filled with sand. Warmth a few inches down in this probably unnatural overburden suggested the possibility that its removal might encourage a rebirth of activity in the vent. With this in mind I subsequently removed the sand in the long narrow taper of the tube to a depth of about 18 inches where the size of the opening became too small in which to work. A knife blade thrust on downward through a thin crack came out wet and quite hot, and water could be heard gurgling at depth, but none rose to fill the tube. Evidently this is another vent which was sealed by geyserite from its own water.

50. PEARL GEYSER is about 725 feet north of Green Dragon Spring and 750 feet southwest of Monarch Geyser Crater.

This feature is No. 68, Pearl Geyser on Peale's map, and was thus named by him because of "---the white pearl-like appearance of the deposit around the spring.---the water bulges, and judging from the surroundings, at times spouts."

This spring, whose action still perhaps justifies the name geyser, is located on a flat sinter mound with sharpest slope toward the west. The pool, which has an extremely irregular margin, is about 22 feet long from north to south and about 18 feet wide. The sinuous edge is marked by a unique and irregular rim which varies from 1 to 6 inches in height and from an inch to nearly a foot in width, dressed in gray to slightly greenish sinter with fine pearly to coarse knobby sponge-like surfaces. Inside the rim the water lies quite shallow on a flat bottom which varies in width from 1 to 10 feet

and is embellished with a variety of interesting sinter forms. From this surface the basin slopes more steeply toward the south end thus presenting a pearly, colorful, flared surface which terminates about 3 feet under water in the elongated, east to west, 3 by 1 foot opening which is the vent. Five islands of spongy-appearing sinter lie in the basin, one about 2 feet long and a foot wide.

I arrived at this geyser on one occasion just prior to the eruption when only the flared portion of the basin contained water at a temperature of 154° F. in a state of gentle ebullition. Shortly thereafter the basin began to fill quite rapidly followed by strong pulsing action at the vent which sent strong waves across the surface of the pool, now quite full of greenish water at a temperature of 180° F. Within the next few minutes an occasional rather strong burst of gas broke the surface splashing the water upward a foot or so resulting in meager overflow all around the margin, after which the surface of the pool became almost completely calm. Returning to the geyser about one hour later I found it in much the same condition as when observed earlier and concluded that I had seen at least one type of eruption from the Pearl Geyser.

On August 20, 1884, Hague's geological party recorded a temperature of 183.2° F. for the water in this geyser.

51 CRADLE MUD SPRING is about 600 feet southwest of Monarch Geyser Crater and about 1100 feet west of Echinus Geyser.

In Peale's time this must have been a rather imposing feature, as it received his No. 69 and the name which it now carries---"---from the curious cradle-like mound which the spring has built."

In 1954 no such formation exists at this feature, it being now a very unpretentious appearing irregularly funnel-shaped vent in the clay flat, in which muddy water is in a rather continuous state of gurgling and pulsing agitation. Wetness in the flared well indicates the solution reaches well up toward the surface at times to form a muddy pool about 4 feet across, but there is no indication of overflow.

52. VIXEN GEYSER is about 550 feet southwest of the Monarch Geyser Crater.

The name appears to have been given by Norris, for in his report of 1881 he alludes to it thus: "Vixen---Eruptions from forty to fifty feet high, each two or three hours." He, however, gave no indling as to the location of this geyser and Peale stated in regard to the feature at this location: "No. 70 is a small geyser on a hard flat mound of gray and reddish geyserite. The basin is about 20 feet diameter and the central orifice only eighteen inches across. The temperature was 180° F."

Irregular reports based on casual observations during the intervening years serve only to indicate that Vixen has been active as a geyser most if not all of the time.

This geyser is located on a low flat mound of dense sinter which is about 12 feet from east to west by 10 feet in the opposite directions. The sinter is normal gray in color, except the area immediately adjacent to the vent which is pinkish to reddish-brown in a band 2 to 3 feet wide. The vent of the geyser is roughly triangular in shape, less than a foot across at the surface and drops straight down for about 3 feet, at which point it is about 4 inches across.

Between eruptive periods the water in this tube is in rather constant agitation, the level changing rapidly with pulsing action through a distance of about a foot.

The interval between this geyser's eruptive phases has not been determined and it appears that these phases may vary somewhat in length and character. On one occasion in the fall of 1952 it was in an eruptive state on my arrival but retired into the vent soon thereafter. During this brief period Vixen displayed her characteristic spiteful mood. Explosive bursts from the small vent which raised a highly disseminated ragged stream of water and associated jets of steam occurred on intervals varying from 40 to 90 seconds, each lasting from 10 to 15 seconds. In general the height of this eruption varied from 2 to perhaps 8 feet but one angular measurement to the top of the highest beads showed them to be 16 feet above the sinter. Meager runoff toward the northeast followed each burst but considerable water from each drops back into the crater to feed the next eruption.

What is believed to have been a different type of eruptive phase was observed late in the afternoon of the following day. This eruptive phase was observed for about 40 minutes, during which 3 extremely active 5-minute periods with 15 to 30 second intervals of quiet between were observed. Relative quiet of 4 minutes followed during which the water pulsed irregularly and noisily in the tube. Two more periods of extreme eruptive violence were observed, one of 4 and the other of 7 minutes, and Vixen was still venting her wrath as I withdrew in the gathering darkness.

During these periods it seemed this little hellion was in a continuous state of spitefully violent action, with burst following

burst so rapidly that a steady stream of hot water flowed across the flat channel to Tantalus Creek. Angular computations revealed that on occasions during this watery orgy, jets reached a height of 30 feet.

Vixen's temperature raised from 192° F. before to 199° F. during her display of madness.

53. TANTALUS CREEK is the main drainage stream from the Norris Geyser Basin into the Gibbon River.

Beginning at the Gray Lakes its sinuous sinter channel meanders northward for a mile to empty into The Reservoir. Emerging, it snakes its way westward another 2000 feet to reach the river. Its major forks and network of minor branches form an intricate drainage system which reaches into every major segment and secluded alcove of the entire basin, and, though its water remains clear, it removes from the basin in excess of 6 tons of dissolved mineral matter each day. The name was given by the Hague Party in 1904, and alludes to Tantalus, a king in Greek mythology.

54. YELLOW FUNNEL SPRING is approximately 300 feet due north of Green Dragon Spring and 1150 feet southwest of Echinus Geyser at the crest of the rise between Phillips Caldron and Coral Spring.

This very pretty feature deserved a name long before being so honored by a Superintendent's committee in 1953.

The spring's pool of clear greenish water lies in a basin which is nearly symmetrically circular, it being about 24 feet long

by 21 feet across. A band of brownish-yellow sediment varying in width from 1 to 2 feet around the inner margin of the basin merges with the yellow of heavy sulfur deposition on the gently sloping funnel-like walls which terminate in an elongated vent 5 feet below the surface of the pool, which is partially choked with rocks. Gentle ebullition, especially from the eastern end of the vent, and a mere trickle of overflow down the slope toward the northeast are the only activity displayed by this spring, whose water temperature is 160° F.

55. PHILLIPS CALDRON is about 125 feet northwest of Green Dragon Spring and 1300 feet south of Monarch Geyser Crater.

This feature was named for Charles Phillips, a former ranger,---. He died very suddenly while in the service in 1927."

In its present state this spring consists of a roughly circular basin about 16 feet long from north to south by thirteen feet across, lying in the gentle, gravelly slope of the rhyolite hillside. On the northern and eastern sides toward the hill the basin is as much as 5 feet deep but of lesser depth on the south and west. During an earlier phase of activity this feature built a clay rim adjacent to its then active center, which now lies as a conspicuous crescent some 20 feet to the south rising 2 or 3 feet above the mud flat then formed. In its present location the surface of the thin muddy water in the basin lies about 18 inches below this old mud flat, but it is apparent that this level varies considerably according to the water supply. The gray muddy water, at a temperature of 198° F., is in a pretty constant state of mild to strong ebullition which sometimes splashes upward 18 inches or more.

Its surface is conspicuously streaked with finely divided black mineral matter, probably sulfur. A coating of the same material left on the irregularly nodular and fluted surface of the basin walls lends the feature the appearance of a battered old black skillet.

56. HYDROPHANE SPRINGS are about 350 feet west of Green Dragon Spring and about 1600 feet southwest of Monarch Geyser Crater in the ancient undulating sinter flat.

The name was given by the Hague Party in 1904, presumably in recognition of the type of opal-like sinter found at this location.

Now as probably then included here are several very irregular, odd-shaped, ragged pits resulting from the collapse of the ancient sinter surface. Two of these sinks, one about 6 by 8 feet square and the other roughly an 8-foot triangle, join below a broken down bridge of sinter, and in each the ragged steep walls stand about 6 feet above the greenish 174° F. water, the surface of which is occasionally broken by lazily rising gas bubbles. Boulders and slabs of slumped sinter clutter the bottoms of these sink holes. A watery steam vent just to the west has a temperature of 199.4° F.

Of the same general character is another and larger pit to the north. It is roughly 25 by 22 feet in size and as much as 8 feet deep above the greenish water, which has a temperature of 188° F. in some places. Sulfur needles are conspicuous on the sheer eastern wall and the tumbled-down sinter blocks on the east and south sides. The water is deep among the sinter slabs and blocks which litter the bottom, and gentle ebullition of its surface is apparent in three

places.

That hydrothermal forces have been at work in this region a great deal longer than in many other portions of the Norris Geyser Basin appears evident. The appearance and great depth of sinter, certainly no less than 7 feet, above the underlying formations compared for instance to that found in most places in the Porcelain Basin, seem to bear out this general line of thought.

57. MEDUSA SPRING is about 600 feet southwest of Green Dragon Spring and 150 feet west of the south Gray Lake on a flat sinter mound.surrounded on three sides by forests.

This feature apparently was named by the Hague Party in 1904; these men, being geologists, probably saw in it some resemblance to the giant jellyfish of the same name. Being almost round and colorful, with small drainages extending from its rim and down the gentle slope of the mound, some likeness to this oceanic form is suggested.

The comparatively shallow basin of this spring is about 13 feet from north to south by 10 feet in the opposite directions with an irregular sinter rim standing seldom more than an inch in height. The spring has a two-holed opening. The largest of the vents, toward the north side, is separated from its southern associate by a foot-wide wall, and the crystal clear, yellow-green water at a temperature of 172° F. bubbles quietly above each of these. Bursts of gas bubbles at depth are audible and faintly jar the ground. The outer rim of the pool, in a band a foot or more wide, is beautiful yellow with a heavy

covering of sulfur, which, toward the center in greater depth of water, appears less dense and presents a brilliant yellow-green color. Meager overflow, following occasional slight increases in ebullition, takes place around the north side.

58. BIG ALCOVE SPRING is about 475 feet southwest of Green Dragon Spring and within 25 feet southeasterly of Gray Lakes Spring.

This spring was so named by a Superintendent's committee in 1927 because of its location in an alcove-like niche in the hillside.

This alcove is in the gray, gravelly clay of the hillside with open side toward the west; it is quite symmetrical with rather steep angled sides and about 8 feet deep terminating in a mass of reddish-brown cobbles of rhyolite. The vent is a ragged cleft in the rhyolite about 6 feet long from southeast to northwest varying in width from about 3 inches at each end up to a maximum of 18 inches.

Water in a highly disseminated mass and temperature of 199.4° F. is more or less continually being spluttered and belched from the vent, some of it to a height of as much as 5 feet. Most of it, however, falls back into the fissure to be splashed about again, and only seepage through the gravel gathers up below to flow in the shallow runoff channel toward Gray Lakes Spring.

59. GRAY LAKES SPRING is about 450 feet southwest of Green Dragon Spring, toward the southern end and within 25 feet of the southeastern shore of the south Gray Lake.

This spring was so named by a Superintendent's committee in 1927 because of its nearness to the Gray Lakes.

It is a roughly circular pool about 10 by 15 feet in greatest dimensions lying at the base of a weathered rhyolite wall, which rises about 6 feet above the water on the east side and breaks down into a gravelly three-foot bank on the south and north. The murky gray 196° F. water which fills the pool is in constant and vigorous agitation, especially at the base of the eastern wall where it is belched upward in irregular ragged splashes to heights of from 1 to 3 feet causing marked wave action and minor runoff toward the lake. At the water's edge on the wall at the back, sulfur has been deposited which blends above with a foot-wide band brown to buff in color. High up on the wall delicate needles of sulfur have been formed.

60. LITTLE ALCOVE SPRING is about 410 feet southeast of Green Dragon Spring and 50 feet north of Gray Lakes Spring.

This spring was so named by a Superintendent's committee in 1927, also because of its location in an alcove-like pocket on the gently sloping, grassy hillside.

This niche is eroded out of the gray clay and gravel of the hillside and the banks, which are slumped considerably, are grass-covered and a maximum of 5 feet high. Lush green grass also lines the neat little gravelly drainage channel toward the lake.

The spring itself is actually a mass of steam vents located in a basin of rhyolite gravel about 2 feet long and a foot wide. This basin is enclosed on three sides by a miniature alcove of moss-like growth which is about 8 inches high at the back and tapers forward to ground level along the sides. The superheated water, at a temperature of 201° F. is shallow in this basin, and kept in a constant state of agitation by the sizzling of numerous blistering hot miniature steam jets which blast their way upward and lift tiny fountains a foot into the air. It is, on first glance, an unpretentious feature but one which is interesting to watch at close range.

61. GRAY LAKES are at the southern extremity of the Norris Geyser Basin in the mud flat basin near the source of the southern branch of Tantalus Creek.

Their normally slightly green-gray turbid water apparently inspired the name used by Hague in the atlas of 1904.

These two rather large ponds, which in seasons of greater moisture merge to form one, lie in a shallow basin whose bottom is much pock-marked by large and small dormant and mildly active vents and crater-like depressions. They spread over an area which is roughly 450 feet from north to south by from 50 to 100 feet in width, and receive some water from springs located in the swampy regions of the forested area to the south, as well as from the following thermal springs: Green Dragon, Big and Little Alcove, Gray Lakes, Medusa, and others unnamed. The temperature of the lake water near the upper end was 136° F. in 1952.

62. BLACK HERMIT CALDRON is approximately 150 feet southeast of Green Dragon Spring and 625 feet northeast of Medusa Spring; it is near the base of the steep hillside toward the southwestern side of a fairly large mud flat which is secluded in the timber beyond the ridge southeast of Green Dragon.

This is a large and active feature that lacked a name until the one used here was accepted by a Superintendent's committee in 1953.

It is a consistently and sometimes violently active mud boiler which was working away at this location even back in Peale's time, who said of it: "---a black sulphur mudhole, 15 by 20 feet, in the timber---." The vat-like steep-walled basin is somewhat larger than in Peale's time, it now being irregularly elongated from east to west and about 36 by 30 feet in size. Its dark gray to almost black muddy solution burbles and plops continuously, and exploded bubbles often send sloppy bits and blobs to considerable distance in all directions. The water level and degree of viscosity of the mix varies considerably with the seasons and surface water supply, and the condition of the mud flat toward the northwest sometimes suggests that overflow has taken place. Agitation is strongest over a considerable area not far from the northeastern end of the basin, where the solution at a temperature of 194° F. is kept in a constant state of turbulence shrouded in billowing clouds of vapor.

63. GREEN DRAGON SPRING is about 1400 feet south of Monarch Geyser Crater and about 1275 feet southwest of Echinus Geyser.

This large and colorful spring was named in 1926 by Charles Phillips, a former Yellowstone Park Ranger, in whose fancy, and quite appropriately, it apparently suggested the lair of such a mythical beast.

A cavernous recess under a yellowish green arch eroded out of a buff-colored, gravelly rhyolite bank about twelve feet high is the rather awesome abode of this spring. The entrance to this cave, some 15 feet in width and perhaps 6 feet above the water, rapidly decreases in size, but one can see back into it about 25 feet to where rock and water merge. The underground pool extends outward from the cavern as a 10-foot channel between highly weathered blocks of varicolored rhyolite to merge in a southwesterly direction with a surface pool about 30 feet long from which a small stream flows into the northern Gray Lake.

Ebullition is heavy and consistent over a considerable area of water adjacent to the mouth of the cavern, where the temperature is about 198° F. and steam in great clouds billows from the entrance. Through this hot veil one can occasionally glimpse even heavier boiling further back in the cavern which sends waves toward the opening. The small lake formed outside on the clay flat has a shallow marginal area from 1 to 4 feet wide beyond which much greater depth is indicated and the water temperature here varies from 185° to 189° F. In general the water is green to grayish green in color. Sulfur deposition on the rocks about the entrance is conspicuous and well developed needles of this mineral are present on the roof of the cavern.

64. RECESS SPRING is about 1050 feet northwest of Green Dragon Spring and about 1100 feet southwest of Monarch Geyser Crater, in an alcove of the forest on a sinter flat at the head of a minor drainage.

This feature appears to have been named by the Hague Party in 1904, apparently in recognition of its location in a recess of the forest edge.

It is a large roughly pear-shaped pool about 42 feet long in the northeast to southwest direction by about 30 feet across, which joins a long narrow southwestward extension into a defile of the adjoining altered rhyolite hill. The somewhat turbid, greenish 183° F. water lies generally shallow over the gently sloping silt-covered sulfur-tinged bottom, except where it drops off into the large irregularly shaped main vent. Gentle bubbling is consistent in several places near the center of the pool and in three stagnant-looking pits in the southwestern extension. Overflow toward the northeast is very small in amount.

65. ORPIMENT SPRING is a name which Hague applied to a feature about 1000 feet west of Minute Geyser toward the western side of the sinter flat in which several branches of Tantalus Creek converge north of the main highway. He associated the lemon-yellow trisulphide of arsenic, orpiment, with the waters of a spring in this location during his earliest work in the Park well before 1900, and showed it on his map of 1904. In 1954, however, it is not easy to relate the deposition of this mineral to any specific spring, but it and its associated mineral realgar, the more reddish monosulphide of arsenic,

may be found at several places in the same general area referred to by Hague.

At a location about 700 feet northwest of Monarch Geyser Crater and 1800 feet northwest of Green Dragon Spring there is a concentration of both arsenic minerals present in the low gravel bank of Tantalus Creek adjacent to a very small spring whose meager overflow of water at a temperature of 156° F. seeps into this stream. Digging in the gravel here I found about an inch below the surface for several feet along the eastern edge of the creek that the gravel is permeated with the brilliant yellow of orpiment below which lie red stringers of realgar. At another location about 70 feet downstream on a small island the platy sinter is conspicuously splotched with the red sulphide. Here also a large sinter block pulled out of the wet gravel was completely covered on the underside with the yellow variety, as was the gravel in the sides of the hole, and the seepage water which quickly almost filled the hole was heavily ladened with it. A red enamel-like coating of realgar occurs as brilliant blotches at many places on the dense sinter of the stream beds of this immediate area.

Associating the origin of these arsenic minerals with the discharge of any certain feature or features in this area apparently cannot be readily accomplished. In the case of the small spring mentioned, a creamy-yellow variety of algal growth occuring as fine hair-like fibers and flocculent matter in the relatively hot water is conspicuously present, but the arsenic minerals are not visibly present much closer than 10 feet away where the spring's meager discharge meets the larger stream. Off hand it seems that these minerals

are present in the seepage waters percolating through the gravels in restricted areas; waters whose origin with respect to any certain feature or features is not immediately apparent.

66. PERPETUAL SPOUTER is about 1100 feet northwest of Monarch Geyser Crater and about 1500 feet south of the south end of The Reservoir near a sharp bend of Tantalus Creek.

This feature's tendency to splutter and spout almost continuously apparently accounts for the name used by Hague in the 1904 atlas.

It issues from an irregular fissure about 13 feet long from northwest to southeast of variable width which actually extends as a minor crack about 8 feet eastward to the creek. The main basin of the feature, located at the southeast end, is about 6 feet long by from 1 to 3 feet in width with rough sinuous edges and an inch-high rim formed of beady and spiny sinter. The overall coloring here is the brownish of iron rust. In the eastern end of this basin the main center of activity spouts and splashes beads of water 6 to 18 inches upward and 2 to 4 feet laterally more or less continuously. Centers of similar but less powerful activity are located northward along the cleft. Related activity is manifest from the crack extending into the stream in the form of small but spitefully violent steam jets which blast the fine sand upward from the bottom with sharp reports and considerable power. This interesting little popper has been frequently referred to as "firecracker spring". The water temperature in the main basin is 192° F. and there is an appreciable and steady overflow from it into Tantalus Creek.

67. THE RESERVOIR is about 2000 feet northwest of the Norris Museum in the southwestern corner of the One Hundred Spring Plain.

The fact that all of the water carried by Tantalus Creek must first be received by this receptacle before passing on to the Gibbon River probably accounts for the name used by Hague in the 1904 atlas.

It is a fairly large pond or small lake about 400 feet long from northeast to southwest by about 150 feet across. The sheer walls which quickly pass from view in the murky-gray water give the impression of great depth, and such may well be the case in places. However, 4 feet was the greatest depth plumbed along the western edge, and the temperature here was found to be about 88° F. in late October 1952.

This temperature being about right for comfortable swimming, The Reservoir apparently was used rather extensively in former years for this purpose by park visitors and employees. Portions of the anchorage for a crude diving board are still in place at a point along the northwestern shore.

My own suspicions that some type of activity takes place on occasions from a vent or vents located in this pond which cause considerable flooding around the southern end appear substantiated by another observation of David Beal's. He has reported that on one trip into this area in August 1948, he observed activity taking place toward the center of the pool which caused the surface of the water to bulge noticeably over a considerable area resulting in appreciable overflow around the edges.

68. CINDER POOL is about 150 feet west of the north end of The Reservoir on the western fringe of the One Hundred Spring Plain.

This pool apparently was so named by the Hague Party in 1904 because of a distinctive and characteristic deposition it alone presents in the form of literally millions of black hollow spheres and partial spheres of sulfurous material resembling "cinders" which float upon its surface.

It is an egg-shaped pool 30 feet long from north to south by 25 feet wide, filled to within a few inches of the surface of the mud flat in which it lies with very muddy gray water. Intermittent bubbles break the surface and ebullition is quite heavy around the north end most of the time. A rather consistent rotary movement of the water tends to gather the "cinders" into a prominent crusty mass around the southwestern third of the pool, thus leaving the rest of the surface relatively clear of these globular forms which have paper-thin skins and are about the size of large BB shot. There is some evidence of meager intermittent overflow especially on the north side, but this was not witnessed. The vent which feeds this pool is probably located toward the northern end in the vicinity of the area of heaviest bubbling, as 30 feet of line was not sufficient to reach bottom at this point. The temperature here, however, was almost 2 degrees less than the 195.8° F. recorded at the opposite end where the depth was only 4 feet.

Directly north of Cinder Pool a violently active small vent in the drainage channel splutters and spouts 194° F. water a foot or

more into the air quite constantly. It has sometimes been called "Perpetual Spouter". Still further north beyond the drainage are several rather large, active, and very interesting thermal features which have not been named. In the general area of the spouter mentioned above are several small orifices around which the brilliantly colored sulfides of arsenic are displayed.

A round shaped pool about 200 feet north of Cinder Pool approximately 8 by 11 feet in size is conspicuous for the very smooth reddish-brown 6 to 8 inch flat margin of dense sinter which surrounds it and the very neat 10 inch runoff channel which carries an appreciable flow of water toward the southwest. The water at a temperature of 192° F. above the dark pebbly bottom splashes violently and continuously from 1 to 4 feet into the air. The green deposit in the warm backwash pool toward the northeast corner is

69. ONE HUNDRED SPRING PLAIN is beyond the low pine-clad hills visible in a northwesterly direction from the Norris Museum, the distance from this building being roughly 2000 feet.

This name was used by Hague in the 1904 atlas apparently in recognition of the large number of springs which are indiscriminately distributed over the flat sinter area which is about 1500 feet long from north to south by 1000 feet wide.

Because of the number and diverse character of the vents present here and the consistently wet condition of the surface, traversing or exploration of this area should be undertaken only by those with considerable experience in thermal areas.

70. ROCK SPRING is about 550 feet west of Sieve Lake near the base of the forested hill on the east side of One Hundred Spring Plain.

This name was used by Hague in the 1904 atlas, presumably because of the rocky location in which the feature is located.

It is in a pit eroded out of the gravelly rhyolite forested slope of the hill which opens toward the northwest and in this direction is about 45 feet long; it is about 35 feet wide and about 15 feet deep. The shallow pool of this spring is irregularly square in outline and about 7 feet across, with a roughly V-shaped extension toward the northwest which is about 4 feet across. Heavily weathered rhyolite cobbles cover the bottom of the pool and similar and larger boulders line its margin, except for that portion formed by the comparatively solid wall at the back of the pit. Ebullition is heavy from one large vent near the center of the pool and three smaller ones near the back wall, and the water, which is crystal clear, has a temperature of 199.4° F. Subsurface drainage toward the northwest takes care of the meager overflow.

71. RECEPTACLE SPRING is about 600 feet due west of Sieve Lake and about 500 feet southeast of The Reservoir in the southeastern corner of One Hundred Spring Plain.

This feature appears to have been named by the Hague Party in 1904, apparently because it serves as a receiving basin for drainage from surrounding springs. The presence of vents of its own which also

supply water seems doubtful. It is a large irregularly-shaped pond or small lake which varies considerably both in size and shape according to the amount of water received from the higher ground which surrounds it on three sides. It also varies in color from emerald to turbid gray-green according to the influx of silt-ladened surface flood water.

72. RAGGED HILLS: These include the jagged highly irregular ragged rock and gravel hills which rise as much as 100 feet above and on either side of, but more especially west of, Tantalus Creek's sinter channel southwest of Monarch Geyser Crater. They were thus named in the Hague atlas of 1904.

These hills are composed of many varieties of rhyolite, mostly in the form of sand and gravel, the original grains of which have been considerably leached forming opal cemented by similar material. The entire strata appears to have been much altered by hydrothermal activity, but subsequent erosion has so changed them that little evidence remains of the location of active vents except at some locations in the lower flanks.

The cavernous character of this formation and the presence of more or less heat have combined in some instances to make better than average shelters in which bears have chosen to spend the winter. Four such caves used in this manner were discovered by Park Ranger Naturalists Merrill D. Beal (father and son) in July 1951, a short distance northwest of Perpetual Spouter. Further investigation by David, the younger man, revealed that the air temperature inside the

caves averaged about ten degrees higher than outside, whether taken in August of October, and that in October the temperature of the ground in all four caves averaged 30 degrees higher than outside.

73. CRYSTAL SPRING is about 1000 feet south of the south end of The Reservoir and about 2300 feet west of Valentine Geyser on the gently-sloping sinter finger north of the Ragged Hills.

It was named by the Hague Party in 1904 for the abundance of crystal-like quartz sand found near by.

The spring is an unpretentious feature located in an area of small fumaroles and "frying pan" steam and water vents. The small discharge of 190° F. water drains northeastward in a green algae-lined channel and is soon lost in the gravelly sinter.

74. VERMA SPRING is about 275 feet southwest of Cinder Pool, on the western fringe of the One Hundred Spring Plain. This feature appears on Hague's 1904 map, and it has been said that he named it thus "because the peculiar deposit of sinter is wormlike in appearance". The validity of this statement is seriously subject to question if it is presumed to have had its origin in Hague himself, as written material by him relative to his work in the thermal areas of the Park on which his 1904 atlas map is based has not thus far been brought to light.

The most prominent feature in this location, and presumably the one which Hague named, is an irregularly shaped shallow pool about 25 feet long in a northeast-southwesterly direction by from 10 to 12 feet across. It is about 275 feet southwest of Cinder Pool in

a wet silty sinter flat which, close to the pool, is deep mud. Most arresting to the attention is the bottom of this pool which is a mass of small and rather large crater-like depressions which in turn terminate in sharply defined holes. Similar holes appear at other places, both on the walls of the depressions and on the highs between them, and together they give the impression of a surface indiscriminately but well punctured by large worm holes. This appearance seems to be a more logical reason for the name. Gas bubbles infrequently rise leisurely from these holes through the 120° F. water, and there is some runoff toward the west.

Adjacent to Verma Spring, about 50 feet southwest, a small spring under a sinter lip discharges 165° F. water which flows into the larger feature. A few inches from the orifice the water is 160° F.; here and for several feet down the small channel the cream-colored algal growth is conspicuously present.

Still further southwest in the muddy sinter flat about 150 feet from Verma Spring are several interesting features. Here a very irregularly shaped, elongated and much larger pool oriented roughly north and south presents a bottom appearance similar to that of Verma. The "worm" holes are perhaps a little less sharply defined, but in addition to them smooth coarsely sinewy and botryoidal silt formations somewhat resemble large worms on the bottom of the pool. The murky green water has a temperature of 122° F. The main pool is roughly 50 feet across each way, but a much shallower portion, also lying above an irregularly indented bottom, extends considerably further toward

the northwest to merge finally with several drainage channels. Two small springs at a slightly higher elevation, about 50 feet southwest, one with a temperature of 167° F. and the other 176° F., are the main sources of water for this large pool.

75. HORSESHOE SPRING was, in the time of Hague's work of 1904, about 500 feet north of The Reservoir on the western side of One Hundred Spring Plain. A spring in this location was mapped by Hague as having the shape of a horseshoe, and was thus named by him. There are several springs in this general location at this time, but none would especially be described as being that shape.

A circular pool about 16 feet across located about 300 feet northwest of The Reservoir is now recognized as Horseshoe Spring. Here the water at a temperature of 192° F. appears dark green toward the center of the pool and dark gray toward the edges of the sharply tapering deep basin in which ebullition is strong toward the south side, less so toward the north. There is no overflow from the feature, but there is evidence of fluctuation in water level. At times it receives some water from the drainage basin to the northwest. Gravelly spine-covered gray sinter adorns the margin of the pool.

A large pear-shaped deep and ominous-appearing pool about 50 feet toward the southeast from Horseshoe Spring with black walls contains clear 183° F. water in a continuous state of agitation, which overflows meagerly toward the south. Black spine-covered sinter pebbles are prevalent around the edges of this pool. It like a number of other very interesting features in this vicinity deserves more consideration

and a name. Especially in this category are several located west, northwest and north beyond the boundaries of the area treated in this publication.

76. REALGAR SPRING: In a location about 900 feet northeast of The Reservoir just beyond the flat sinter divide which separates the One Hundred Spring Plain from the Realgar Creek drainage, Hague's 1904 map shows "Realgar Spring", and it is assumed that he associated the deposition of the red monosulfide of arsenic with it.

In 1954, however, it is difficult to relate the occurrence or source of this mineral to any certain spring or thermal feature in this area. Several small springs in this vicinity together with seepage water are the source of Realgar Creek. Red blotches of this mineral are common on the dense sinter of small water courses, and occasional small patches away from the stream display sinter in a shattered condition as though disturbed by a minor eruption; here the red tingeing of the rock flakes is rather conspicuous, but the presence of any type or degree of thermal activity is not apparent. That realgar is being deposited in this area is manifest, but to relate it to any certain thermal feature or features will require further investigation and study.

77. REALGAR CREEK has its source in the small springs located about 900 feet northeast of The Reservoir just beyond the low divide which marks the northern boundary of The One Hundred Spring

Plain. Flowing northeasterly for about 900 feet through an area of diverse thermal activity, which includes several small springs whose discharge considerably augment its size, it then turns abruptly northwest to continue its course through an area of forest and marshy ground about 1200 feet further before emptying into the Gibbon River.

The stream owes its name to Hague, who thus designated it on his 1904 map.

Common in the stream channel where it traverses the thermal area and in erupted patches of sinter close by are similar occurrences of realgar to those mentioned under Realgar Spring. People of by-gone days must have believed that these waters contained curative qualities, as the dilapidated remnants of a crude log bathhouse and wooden trough-like tub may still be found located near one of the larger unnamed pools close beside the stream and about 500 feet from its source. The bottom of this pool is a hummocky surface covered by a thick mantle of cream-colored algal growth. Up stream from this pool about 200 feet two other features, one an 18-foot ragged fissure lying at right angles to the creek and the other a large irregularly shaped pool of warm water apparently discharge water on occasions, as each displays conspicuous deposits of brown iron oxide where overflow occurs. Several other thermal features adjacent to this stream and in a rather large area to the northeast are sufficiently significant to justify names and investigation and study than has thus far been given them.

Whether yours has been a trip through the Norris Geyser Basin in fact or in your easy chair by the fireside, I hope you enjoyed the experience thoroughly. If you actually set your feet upon the trails, then I am certain that you found this hydrothermal area an intriguingly interesting place and saw many things of rare beauty.

If I am accountable for your trip into the Norris Geyser Basin, then it is my most sincere prayer that you left nothing there but your lightest footprint, that you did nothing in any manner to detract from the beauty you enjoyed, and that the impact of your presence there was no greater than that of the first human observers of this uncut jewel who left nothing more than a few obsidian chips near favored campsites to remind you that they, the Indians of perhaps many tribes, also found it a pleasant place to while away the summer moons during countless years before the first white explorers set foot upon it.

Winter in the Norris Geyser Basin

The Norris Geyser Bason on a sub-zero day is truly a winter wonderland. Vapor in a mighty column rises majestically into the calm atmosphere, its base constantly replenished by jets and columns ejected from literally countless small and large orifices. A visitor in the basin, thus constantly enshrouded in a fog of swirling whiteness must move cautiously and for a fleeting glimpse of one of the features must await the whim of a passing breeze to move the dense vapor pall. Conditions for picture taking and even reasonably good general observation in the Porcelain Basin on one memorable day after a 40 below zero night were not suitable until early afternoon.

Adjacent to some vents and low upon the ground at many places ice formations of almost incredible beauty are presented, some too delicate to withstand even the wan rays of a winter sun, others so massive and rugged as to seem quite able to last through the heat of summer. And the "ghost trees"! These ice and snow encrusted trees can resemble almost anything: a frozen fairy or a statuesque beauty, a grotesque white witch or a solitary sentry with bowed head and drooping limbs or a white army stolidly awaiting orders. These are things of unsurpassed and indescribable beauty adorning the fringes of the basin.

Water belched from the Black Growler together with snow forms an ice mass around the edge of Valentine's Crater which may be several feet thick, in which is encased irregular layers and blobs of gelatinous silica frozen out of the water as it falls upon the succeeding

cold surfaces presented between snow storms. Droplets ejected into the crater from this superheated vent fall like a chilling rain and build up closely grouped delicate ice stalagmites or spicules on the bottom of the crater. In many places there are masses of fibrous ice rising from 1 to 6 inches above the ground which appear to have been extruded from the ground. These fibrous phenomena often raise areas of soil and sinter which may be a few square inches or several feet in size, and they, like the fantastically delicate and beautiful crystal formations which compose the outer layer on the "ghost trees", seem to be associated with the periods of extreme cold, and like them melt and fall away under the rays of the sun. The aesthetic effect produced by encasing trees in snow and ice to form "ghost trees" is extremely pleasing to the human eye, but after successive years of it the trees themselves often "give up the ghost". Those to leeward of the Valentine Crater thrived rather well while the Black Growler was only a roaring superheated steam vent. More recently, however, prevailing westerly winds heavily ladened with moisture from this vent after it began belching so much water and from the Ledge Geyser's accelerated activity have so consistently and completely encased these trees in ice each winter that many have gradually given up the fight for survival. The death of several other trees west of Black Growler may also, it appears, be logically charged to the same cause, as shifting moisture-ladened winds are known to have heavily drenched them. The death of many trees and the steady recession of the forest edge, however, may probably be attributed also to an increase of heat

in the ground which has been recognized in this area for several years.

In general one may as readily walk about in most of the geyser basin area in winter as in summer and find the various vents expressing their usual activity without regard for the low temperatures of the atmosphere. There are wet and muddy spots, and the dense pall of vapor reduces visibility, thus demanding one's caution to keep out of trouble; but on the warmer clear winter days these same clouds of vapor create an extremely photogenic and spectacular sight. The greater part of the geyser area because of ground heat lies almost free of snow, but the board walks, because of the insulation which they provide from the heat, may be heaped with four feet of snow, thus resembling a great white snake wending its way into the basin.

The Norris Geyser Basin at this time of year is an enthralling spectacle whether viewed from far or near. Countless vents emitting vapor so dense it appears like white smoke create an appearance resembling a diverse collection of factory stacks. Sulfurous fumes on the frost-ridden breeze may even heighten this impression momentarily as one approaches, but the illusion is quickly dispelled by a feeling of awe and admiration as he moves closer to view the phenomenal beauty of the region's frozen sentries. Pressing on through the veil of steam he soon becomes a part of a weird enchanted land seemingly far from all things mundane where the ever alert forces of jack frost wage a constant but ineffective battle to place their crystalline seal upon vulcan's doors.

Historical Personalities

Historical records show that General Gibbon was in the vicinity of the Norris Geyser Basin as early as 1871, and that explorers Topping and Woodruff in 1872 were the first white men to actually see and set foot upon it. The man whose name the basin bears, Philetus W. Norris, according to his own statements, first saw the area in 1875 when he hurried through it on a personal trip with guides Wyman and Beltizer. Mr. Norris, however, a man not the least backward about claiming credit for himself, chose to ignore the simple statement appearing in the Annual Report of the Superintendent of the Yellowstone National Park for the year 1872 in which the Park's first Superintendent N. P. Langford said: "A party of tourists from Bozeman also discovered a similar basin between Mammoth Springs at Gardiner's River and the Firehole Basin." This of course was a clear allusion to the discovery of the new basin by Topping and Woodruff in that year and their subsequent trip to show it to the Stones. But Mr. Norris, who became Superintendent of Yellowstone National Park in 1877, blithely stated in his report of 1880: "To the Upper, Lower, Midway Geyser basins---and other less important---Heart, and Shoshone Lake, early discovered by others, my own explorations have added the Monument, the Norris, and the Paint Pool basins upon the Gibbon or its branches." Thus did Norris lay claim to the discovery of an important thermal area which in fact he did not even see until three years after it had been found and no doubt at least partially explored by at least four white people. Similarly does he seem to have ignored other observations

of these same four people, who could hardly have missed seeing Obsidian Cliff and Beaver Lake on their way to the new geyser basin, when he stated in his report as Superintendent in 1878: "As discoverer, and probably yet sole white visitor, I from its group of white geyser cones name it the Monument Basin, and trust no one will ever question the appropriateness of Beaver Lake, Obsidian Mountain, and other names given to the localities which I discovered and explored."

In spite of his great desire to be first and a proclivity for naming things after himself, it must be said to the credit of Philetus W. Norris that he was a man of great energy within whom dwelt the true spirit of an explorer and a sincere desire to make Yellowstone Park available to the people. For his services he received little or no compensation. He was the second Superintendent of Yellowstone National Park and served during the years 1877 to 1881. Considering the natural hazards and handicaps of the times and the limited amount of money placed at his disposal, a great deal of exploratory work was accomplished and the first program of systematic trails and roads, other than the then-existent road to Cooke City, was begun and partially completed. As resident Superintendent he was present in the Park only during the spring, summer and early fall months. J. C. McCartney, B. F. Bush and C. M. Stephens served successively as Assistant Superintendents under P. W. Norris and resided in the area during his absence in the winter. Following the route which he explored in 1875 P. W. Norris laid out and supervised the construction of the first road from Mammoth Hot Springs to Norris and thence on to the Upper Geyser Basin in 1878.

No matter what others may have done before him it is evident that P. W. Norris, responding to the ever-present urge to explore far and wide in Yellowstone, carried on exploratory work within what he called Norris Geyser Plateau previous to 1881 and later named the Norris Geyser Basin. From statements in his 1878 report he must be credited with the discovery and naming of Monument Geyser Basin, and it is apparent from the following quotation from his 1878 report that he explored in Monument and Norris Geyser Basins and also the area now called the Artist Paint Pots.

"Upon the crest of the western mountain spur, rising nearly vertical full 1,000 feet above the head of the Grand Canon of the Gibbon, is a firehole basin, containing, probably, less than 5 acres, yet one of the most beautiful and interesting within the park. There, mingled with hot springs and spouting geysers, are 12 pulsating geyser cones from 2 to 20 or 30 feet in height, in form and character similar to the famous Liberty Cap; and, like that, fully one-half of them are extinct and slowly eroding away. Others are still active; one of them a tall fumerole, pulsating like the exhaust-pipe from a huge Corliss engine, and another has the orifice and terminal of its cone positively horizontal, instead of vertical. Although there are still at least one powerful geyser and a hissing fumerole plainly audible for miles, yet there is abundant evidence that this basin is in all respects but a dwindled remnant of what it was at no remote period when its matchless geyser supplied four separate and distinct torrents of hot water in hissing cascades adown the mountain crags."

"Along and near the upper canon of the Gibbon, are pulsating geyser cones of both yellow and crimson, paint-springs, and rivulets

of nearly every color, geysers throwing their jets some at least 100 feet at an angle of 40° to 60° , instead of vertically as in the old basins; and in the open basin along the road, beside many small but beautiful geysers, is a large crater formed so recently that many pine trees within and around it still retain their seared and mud-laden leaves."

In 1872 Dr. F. V. Hayden, then United States Geologist and head of the U. S. Geological Survey of the Territories, headed an expedition which spent several days exploring the Firehole Geyser Basins in August of that year. This expedition spent some time on or about August 21st in the vicinity of the area now known as Madison Junction, and some members explored up the "Gibbon's Fork" of the Madison as far as "a fall of nearly 100 feet in height" which was of course what is now known as Gibbon Falls, height 83 feet. None of this party actually reached the Norris Geyser Basin in 1872, but Dr. Hayden then named the Gibbon River after General Gibbon of the U. S. Army who had explored it somewhat the previous year.

In 1878 Dr. Hayden, still United States Geologist and head of the Survey known then as the U. S. Geological and Geographical Survey of the Territories, again led an expedition into Yellowstone National Park to elaborate upon and extend the work which he had begun in 1871 and continued in 1872. Dr. Hayden placed Dr. A. C. Peale, who was a medical doctor as well as a mineralogist, in charge of that part of the expedition assigned to investigation and mapping of the thermal

areas in the Park. So it was that Peale and his assistants, using the road just completed by P. W. Norris as a means of access, spent about one day and a half exploring and mapping the area which they named the Gibbon Geyser Basin in order, as Dr. Peale wrote in his report of 1878 "...that it will be uniform with the names of the other localities." This name, however, never came into popular usage.

In 1883 Arnold Hague, an emminent geologist, was made geologist in charge of the Yellowstone Division of the U. S. Geological Survey, and "a thorough geological and topographical survey of the Park and adjacent country was organized. It embraced a systematic invesitgation of the hot springs and geysers every year up to and including 1893, and these investigations were supplemented by further observations in 1896, 1897, 1902, 1911, and 1915...." The results of much of the work undertaken by the men active in this program appear in two publications by the U. S. Geological Survey. The first of these, Part II of Monograph XXXII <u>On the Geology of the Yellowstone National Park</u>, was published in 1899, and was followed in 1904 by a companion volume, the folio atlas. Valuable articles on various phases of their work were written by members of the Division and published in different scientific journals, but Part I of the monograph which was to deal particularly with the features in the central portion of the Park remained unfinished when Hague died in 1917. These apparently unavailable writings together with field notes pertinent to them perhaps contain information which would clear up a number of questionable matters relative to the Norris Geyser Basin. Some valuable data for use in this work was found in the special articles alluded to above, and

continual reference was made during its preparation to the map of Norris Geyser Basin in the 1904 atlas.

The Road to Norris Geyser Basin

The Norris Geyser Basin, which prior to 1877 could be reached only by Indian and game trails, has been made ever more accessible to the people who have clamored to see it and the other wonders of this great National Park. In 1877 Norris improved the trail which he had explored in 1875 from the forks of the Firehole (junction of Firehole River and Nez Perce Creek) to Mammoth to the status of what he called a "bridle-path", and in the following year he superintended the building of the first road from Mammoth Hot Springs to Norris Geyser Basin. The "Norris Road" began at the mouth of Clematis gulch and skirted the Mammoth Terraces on the northwest by a series of heavy grades and switchbacks and a long heavy pull through "Terrace Pass", emerging into the upper valley of Swan Lake. Terrace Pass, which is the gap between Terrace Mountain and Clagget Butte, is the Snow Pass of today. The road then headed southward and from a point just west of Golden Gate to the southern end of Beaver Lake traversed essentially the same route as the present highway. It then ascended the steep grade to the east and passing the Lake of the Woods on the right took its way down what is now known as Solfatara Creek, to the stream known then as the Norris Fork, which we now call the Gibbon River. Emerging here in the broad meadows adjacent to the present location of the Norris Ranger Station, the Norris Road crossed the Norris Fork and headed southwestward

to bisect the Norris Geyser Basin in much the same manner as the present road, except that in those days the route went over the hill in the present location of the parking area and rejoined the present road location at a point near the Minute Geyser. In the section of the road from Mammoth Hot Springs to Norris Geyser Basin only two major changes have been made since Norris' time, and certainly to him must belong the everlasting distinction of making not only the Norris area and the geysers of the Firehole drainage, but also the Lake and the Grand Canyon, available to wheeled vehicles as early as 1881.

Norris had this to say about the road building project in his Annual Report of December, 1878:

"I thus quickly organized a party of some 20 well armed, mounted, and equipped, resolute and reliable mountaineer laborers, and, with only one baggage-wagon, rapidly constructed a road three miles up the lofty Mammoth Hot Springs terraces, and through an excellent pass to the West Gardiner Valley.

"Subsequent careful and long continued explorations of this route proved it, although difficult and dangerous of construction through several canons and firehole basins, the most direct and practical one for a wagon road across the park.

"As Barronette's party had left and Professor Hayden's not reached the park, we were doubtless for a time the only white men within or near it, requiring constant caution in scouting and labor, as well as in care of animals and making and guarding camp. Despite these annoyances, we crossed the terraces, rapidly bridged the first branch

of the Gardiner, forded the next two branches, and ascended the last through a two-mile canon, and, with nearly a half mile of bridge and causeway, crossed the foot of Beaver Lake.

"Obsidian (Obsidian Cliff) there rises like basalt in vertical columns many hundreds of feet high, and countless huge masses had fallen from this utterly impassable mountain into the hissing hot-spring margin of an equally impassable lake, without either Indian or game trail over the glistering fragments of nature's glass, sure to severely lacerate. As this glass barricade sloped from some 200 or 300 feet high against the cliff at an angle of some 45 degrees to the lake, we--with the slivered fragments of timber thrown from the heights--with huge fires, heated and expanded, and then, men well screened by blankets held by others, by dashing cold water, suddenly cooled and fractured the large masses. Then with huge levers, steel bars, sledge, pick, and shovels, and severe laceration of at least the hands and faces of every member of the party, we rolled, slid, crushed, and shoveled one-fourth of a mile of good wagon-road midway along the slope; it being, so far as I am aware, the only road of native glass upon the continent.

"Then, by a full mile of grade, we flanked Beaver Lake, skirted a dashing rivulet of green alum-water, through a fine pass, and beside a lone lake (Lake of the Woods) in a forest of dense pines to the lovely valley of an unknown fork of the Gibbon, (Solfatara Creek) descended this to, and three miles through, an unexplored but extremely active and interesting firehole region, (Norris Geyser Basin) and skirting another (Chocolate Pots) near the second falls and canon to the wild flax and clover-covered park-bed (Gibbon Meadows) of an

ancient lake, to the head of the Grand Canon of the Gibbon.

"Thence, without the guide of even a game-trail, by immense labor, and twice crossing the stream, we for some four miles traversed its canon, (Gibbon Canyon) nearly a half mile deep. We then emerged through an ancient channel, and skirted (the Norris road at this point was on the plateau south of Gibbon Canyon) the very brink of a precipice nearly a thousand feet above the 80-foot falls (Gibbon Falls) and foaming rapids, and six miles of open pine-clad terraces to Howard's road from Henry's Lake, an estimated distance of 45 miles from the Mammoth Hot Springs, mainly through a region heretofore totally unexplored; then 15 miles farther through the Lower Firehole and midway to the upper geysers, our wagon being the first to make a track along the Upper Firehole River."

Two changes were made in the location of the road between Mammoth and Norris by the Corps of Engineers, U. S. Army, between 1883 and 1885, Captain Dan C. Kingman in charge. The first of these involved construction of a new road from Mammoth to Swan Lake Flat to eliminate the steep road through Snow Pass in regard to which the following is quoted from Captain Kingman's report:

"The...piece of new work...was commenced in September, 1883, and finished June 12, 1885....The new road follows up the west fork of the Gardiner River....This route, offered no serious obstacle to the construction of a road until the head of the Canon was reached. Here, for about 1,000 feet, the rock walls approached each other, and were nearly vertical, and the little stream in the canon had a fall of 60 feet....This quarter of a mile was by far the most difficult and expensive piece of work undertaken in the Park.

"At the mouth of the canon the wall was nearly vertical, and sufficient roadway could be secured only by cutting and breaking down the solid rock over 100 feet. The cost of this would have been excessive. The road in this portion was supported by timber trestles.

"The total length of the structure is 224 feet, and its cost was $3 per running foot.

". . . The work was accomplished without accident or injury to any one. The benefits conferred . . . are very marked. The distance from Mammoth Hot Springs to the Geysers . . . is reduced 1-1/3 miles, and the height . . . in reaching the Swan Lake Plateau is reduced 250 feet. . . . The total cost was $14,395.39."

In recognition of Capt. Kingman's work on this road the gap opening into Swan Lake Flat above Golden Gate was named Kingman Pass.

The second change involved relocation and construction of the road between Beaver Lake and Norris Geyser Basin; in regard to this job Capt. Kingman had the following to say:

"The . . . new work is the road from the south end of Beaver Lake to the hotel at Norris Geysers Basin. It was begun and finished in the summer of 1885. The object of this road was to avoid a series of obstacles due to bad location.

"The new location follows a lower level, . . . The total length of the section is 7 miles, and its cost . . . was $6,269.80, or about $993.62 per mile, . . .

The road up "Golden Gate Hill" was further improved under the direction of Capt. Hiram M. Chittenden, also of the Army Corps of Engineers, in 1899. In summarizing in regard to this road Chittenden

had the following to say in his report covering the year 1900.

"This hill rises about 1,000 feet above the level at the Mammoth Hot Springs hotel in a distance of 4 miles. . . .

. . . . . .

"The direct line between these two points, and the one where the best grades and most interesting scenery were to be found, lay through an excessively difficult tract of limestone rock. This singular formation, to which local usage has given the name "hoodoos", is quite unlike any other to be seen in the Park, if, indeed, its like is to be found anywhere else in the world. . . .

". . . To carry a road through it was too expensive a matter to be attempted with the funds which Lieutenant Kingman had at his disposal, and it was necessary to follow a line further east, near the immediate valley of Glen Creek, . . .

"It has been intended for several years to change this location, . . . It was accordingly decided to take it up at once and not undertake any other work until the balance remaining from the completion of this could be known."

In regard to actual construction of this improved section of the Golden Gate road Mr. C. E. Sherman, Assistant Engineer, had the following to say in his report to Capt. Chittenden:

". . . Leaving the old wagon road near Observatory Hill, the new road winds around the foot of Jupiter Terrace . . . gaining the top by means of a loop upon the hillside, . . . thence the road curves around upon the hillsides at a continual upward grade to the . . . "Hoodoos" . . .. Through these immense rocks the road passes almost on a level for 1,800 feet. It then comes upon hillsides of trachitic

rock, requiring tedious blasting, and gains the Golden Gate by a gradual ascent. There are no minus gradients . . . excepting two slight indentations in the "Hoodoos", and the average grade is about 5½ or 6 per cent . . ."

The cost of this new road to Golden Gate, completed in 1899, was $15,360.38, not including a new bridge and road through Golden Gate Canyon, proposed by Chittenden in 1899 at an estimated cost of $15,000.

Regarding this improvement Capt. Chittenden had the following to say in his report of the year 1900:

"The condition of the old wooden bridge at this point had become such as to excite general uneasiness and concern among the traveling public, and although still safe . . . its reconstruction could not long be deferred . . . After a thorough study of the site it was decided that a concrete structure would be better adapted to the situation than any other. . . .

"It was decided to build the new viaduct in a series of arches. . . .

"The execution of the work was of extraordinary difficulty. There was an almost constant gale of wind through the canyon which was frequently of such force as to compel a suspension of work. During the period of concrete mixing this was a most troublesome matter, and it was found necessary to commence work each day about daylight and suspend about 11 a.m. The site of the work was very contracted, . . . It was, moreover, a dangerous situation, being on the face of the cliff where any misstep would cause a fall of from 20 to 75 feet.

"The necessity of interrupting tourist traffic as little as

possible made great haste necessary . . . . During the time of actual construction a temporary road was provided via Snow Pass. . . .

"The old bridge was closed to traffic . . . just four weeks . . . . . work continued on the viaduct and through the canyon, and was not completed until nearly the end of October. One interesting feature . . . was the removal of the large rock which stood at the entrance to the old bridge and partially blocked the roadway . . . between it and the cliff. As it was the unanimous desire of those familiar with the Park that this unique and picturesque feature be retained, the rock was broken off, lifted about 6 feet to the new grade, moved out about 6 feet and down the road about the same distance, where it was set up on a new foundation, . . .of concrete 3 by 3 feet and 24 feet high. . . . This rock weighed about 23 tons, and as its removal took place on the steep face of an unstable cliff it had to be managed with great care. It was done under the personal direction of Foreman Robert Walker, with a force of four men. The whole operation consumed five days and cost $40, not including the concrete foundation which cost about $80.

". . .it was planned to rebuild the entire road through the canyon a distance of 2,000 feet. The grades were reduced from 15 and 18 per cent to 8 per cent, and the roadway widened . . . so that teams can everywhere pass. . . . About two-thirds of this work was done in the season of 1900."

Mr. Sherman, in charge of the improvement as far as Golden Gate the previous year, 1899, in his report to Major Chittenden in 1900 had the following to say among other things concerning the construction

of the new Golden Gate bridge:

" . . . . . .

"Labor and subsistence are probably as high here as in any part of the United States. Ordinary labor is paid . . . $1.50 per day, of eight hours, and subsistence. This latter costs about 35 cents per day per man. All laborers while making concrete received 25 cents per hour.

"Transportation rates are high. The rate from Cinnabar, the railroad terminus to the Golden Gate, a distance of over 11 miles, is 28-3/4 cents per ton-mile."

The total cost of the new bridge and 2000 feet of improved road on up through Kingman Pass was $12,501.83.

In the early 1930s the road up Golden Gate hill and on through Golden Gate Canyon was further improved. Grades and curves were reduced, and in the Hoodoos the section which included the route through Silver Gate was eliminated from the main highway but was left open for one-way travel. A project to widen the road through the canyon was initiated in the fall of 1932 and completed in 1933. This was to include construction of a new viaduct to replace that built in Chittenden's time, and also a tunnel about 200 feet in length through the point of rhyolite rock beyond toward Kingman Pass. Using a system of counter balanced steel beams to carry the increased width of roadway a new viaduct was built at the site of the old one, but the tunnel portion of the project had to be abandoned because of the highly fractured and thus unstable character of the rock through which it was projected. To accomplish the desired widening the point of rock was eventually removed, and the entire project, which involved less than one mile cost approximately $135,000. The rock mentioned by Chittenden above was again

carefully handled and now stands at the eastern entrance to the improved viaduct.

Early Travel and Associated Incidents

Prior to 1883 persons desiring to see Yellowstone Park found it necessary to make an extended trip by stage or saddle horse, as the Northern Pacific rail head was still east of Livingston, Montana, in 1882, and at that time people coming from the west found the rail terminus at Beaver Canyon, Idaho, 110 miles to the southwest. In 1883 the branch line of the Northern Pacific from Livingston, Montana, terminated at Cinnabar, Montana, which was located about three miles down the Yellowstone River from the present site of Gardiner, Montana. Passengers arriving there by rail were picked up by stages operated by Wakefield and Hoffman and transported to the hotel at Mammoth Hot Springs, which was in that year sufficiently completed by Rufus Hatch and Co. to receive guests during the latter part of the tourist season.

From about this time and on through the 80s visitors at the north entrance of the Park by rail were transported to Norris Geyser Basin and on to the Geyser Basins along the Firehole River in stage coaches operated by George Wakefield for the Yellowstone Park Association, a company which had been formed to operate hotels at Mammoth Hot Springs, Norris Geyser Basin, Grand Canyon and Yellowstone Lake. The stage fare from Mammoth to Norris in 1887 was $4.00 per person; the round trip fare from Mammoth to Old Faithful and return was $18.00.

Visitors coming into the area from the rail head at Beaver

Canyon, Idaho, during this period could obtain state transportation through the facilities of the Bassett Brothers who operated a stage line from that point into the Park.

Those hardy individuals who could and did provide their own saddle horse or horse drawn vehicle for transportation to the Park boundaries were privileged to use the road system, and an ever-increasing number beginning in the early 80s and extending down through the years until this mode of travel was made obsolete by automobiles availed themselves of this opportunity to see Yellowstone Park. They were self-sufficient, and camped out as they progressed from one scenic point to another. For them no hotels were needed, and those who traveled from Mammoth to Norris Geyser Basin before the turn of the century usually would break the distance in two with a camp in the upper end of Willow Park. The second night of easy traveling found them at a good camping area in the general vicinity of the present Norris Ranger Station at which point they could stop over as long as necessary to view the thermal features of the Norris Geyser Basin. These were the original "sagebrushers", the folks who came to see the place in the free and easy manner, the modern counterpart of whom is the present day auto camp visitor with his tent or trailer house.

Prior to 1917 four footed horse power provided most of the means of transportation for the somewhat more than 450 thousand visitors who had toured Yellowstone up until that year. These included people of all degrees of affluence, from those who came with their own saddle horses or horse-drawn vehicle to those who came by train to the park boundary, then made the trip around the park by stage coach and stayed at the hotels. In between these was another group, the members of which

also made the trip to the park by train, but finding the hotels and Concord coaches a bit beyond their means or desiring to travel in a little less style and closer to nature, created a need for another mode of touring the park.

This was met from the early 90s until travel within the area by bus and private car was well established in 1917, first by Mr. William W. Wylie and later also by the company of Shaw and Powell. Wylie is recognized as the pioneer in the camping business in Yellowstone Park, he having been engaged in conducting camping parties in and through the park and providing his patrons with movable camps as early as 1892. By 1896 Wylie had been permitted to establish four so called "permanent camps" to facilitate handling of his patrons, and one of these was located in the general vicinity of Apollanaris Spring on the road to Norris Geyser Basin. In 1907 this camp was replaced by a similar one at the head of Swan Lake Valley about 6 miles from Mammoth.

In the late 90s and early 1900s permits were issued to a rather large number of persons to conduct camping parties and use movable camps to take care of their patrons. One of these was to Amos Shaw, who in 1900 became associated with John D. Powell. In 1913 the Shaw and Powell Camping Company was accorded privileges similar to those enjoyed by The Wylie Permanent Camping Company, and in that year established permanent camps for the guests they conducted through the park. Their camp between Mammoth and Norris Geyser Basin was located at the lower end of Willow Park shortly south of the junction of Obsidian Creek with the Gardiner River.

For the use of those who came to the park with their own horse-drawn vehicles and camping equipment, six camp areas were designated

on the road from the north entrance to Norris Geyser Basin. These camping tourists had no need for hotel accommodations.

Those, however, who desired the deluxe facilities of the day found modern hotel accommodations at Mammoth Hot Springs from 1883 on, and in 1886, according to Acting Superintendent Moses Harris, speaking of the hotel at Norris Geyser Basin in his report of that year: "A good hotel has been erected upon the new site, and it appears to be well located." In his report of the following year Superintendent Harris says: "On the evening of July 14 the hotel of the Park Association at the Norris Geyser Basin was totally destroyed by fire. . . . A hotel camp was at once established by the Association and . . . I permitted the company to begin the erection of a temporary building subject to your (the Secretary of the Interior's) approval." In regard to this structure Harris further stated in his report of 1888 that: "The building at the Norris Geyser Basin is a long narrow one-room building built of one inch pine boards. It has some twenty small sleeping rooms, is cold and open, with no appliance for heating beyond a sheet iron stove in the common hall." Poor as it was, this facility apparently was used until 1892, as Acting Superintendent George Anderson (Army Captain) reporting to the Secretary of the Interior in that year says: "The old Norris lunch station was burned in May, and is now being conducted under canvas." He further stated: ". . . the Norris lunch stations should be rebuilt, and have a few rooms for the accommodation of such parties as desire to spend the night."

Apparently this station operated under canvas for about ten years and dispensed a large number of meals, as Acting Superintendent

S. B. M. Young (Army Captain) in his report of 1897 shows that on July 27, 561 people were fed at the Norris Lunch Station.

Demand for better facilties in the Norris area apparently dictated the building of a new hotel, as Acting Superintendent John Pitcher (Army Captain) states in his report of 1901: "A new and very comfortable little hotel has been constructed at the Norris Geyser Basin. It has been built on a far better site than that occupied by the old lunch station . . . ." The need for this facility apparently continued until the advent of automotive travel in the park.

An historic incident of interest and importance associated with the hotel at Norris was the first arrest and conviction for poaching in Yellowstone National Park. Reading in Acting Superintendent (Army Captain) Moses Harris' annual report of 1887 it is apparent that in January of that year one William James went to the Norris area and apparently was quartered at the Norris Hotel, ostensibly for the purpose of hauling lumber "between the Grand Canon and the Norris Basin." Quoting further from Harris' special report to the Acting Secretary of the Interior dated Mammoth Hot Springs, Wyo. April 24, 1887:

A few days ago I received information which caused me to believe that James was engaged in trapping beaver on the Gibbon River, near Norris. I accordingly sent a party on the 20th instant, at night, on snow-shoes, to this locality, with instructions to make diligent search . . . . . The party, with a sergeant of my troops in charge . . . having found three beaver traps set and baited along the Gibbon River, went to the Norris Hotel, and, . . . found in an out-building, which was used by James . . . , five beaverskins and one lynx-skin. . . . the sergeant, in obedience to my orders, arrested James, and, . . . sent him

to this place on the 22d instant. James, when examined by me, admitted that he had trapped and killed the beaver and lynx, and also that he had, in company with one Brown . . . killed an elk near the Falls of the Yellowstone, in the month of February last. There appearing to be no doubt whatever as to the guilt of this man James, I have this day summarily expelled him from the Park."

James, probably unwittingly but none the less definitely, further established a claim to a place in history when later the same year he engaged in the first stage holdup in Yellowstone National Park. Acting Superintendent Harris reported on July 7th that ". . . on the night of the 4th instant one of the stages . . . was stopped by footpads about 1 mile from the town of Gardiner, and about the same distance within the limits of the park . . . and the passengers robbed of money to the amout of $16." Not until a year later, according to Jack Ellis Haynes' statement in The Westerners Brand Book, when one of the culprits talked too much over his liquor was it established that: "The two men were William James and his friend Charlie Higgenbotham. . . . Upon their arrest, . . . they were tried, found guilty, fined $1,000 each, and sentenced to serve one year in the Montana penitentiary."

These incidents, and a forest fire in the Norris area which apparently burned over an area of a thousand acres of more, remind us that the tendencies of men and mother nature were much the same in the Park's early years as now. Acting Superintendent George S. Anderson (Army Captain) reported in 1893 that on July 10 a fire ". . . occurred on the roadside, about half a mile north of the Norris station. Capt.

Scott, who has investigated . . . believes it originated with the party building the new road at that point. . . . it is possible, however, that it originated in a cigar carelessly thrown from a coach by a passing tourist. . . . The country recently burned over is very irregular in outline, and extends northeast from the Norris Station about 7 miles, and in places is 2 miles or more in width."

In 1917 the Yellowstone Park Transportation Company, which b then had absorbed all other companies engaged in the transportation business in the park, with the purchase of 100 ten-passenger busses and 16 seven-passenger cars abruptly switched from stage coach to automotive travel and thus materially speeded up the movement of visitors in the park.

Thus it was that several hotel facilities were rendered useless, and in that year, 1917, the Norris hotel was abandoned as was the Fountain Hotel in the Lower Geyser Basin. Both of these structures, however, remained until razed in 1927.

Automobile travel in the park was first permitted on August 1, 1915, and it is interesting to note that 50 cars came in on that first day after having paid a fee of at least $7.50 for a single trip or $10 for the season, and a total of 958 cars entered before the season ended.

Regulations governing the use of automobiles in the park were very strict from the beginning, and for the first two or three seasons they were allowed to travel only according to schedule on the main loop road. For instance cars bound for Norris Geyser Basin were not permitted to leave Mammoth Hot Springs before 6:45 a.m. or later than 7:15 a.m., and they could not arrive at Norris Junction before

8:30 a.m. or later than 9:00 a.m.

In 1917 the fee for private automobiles to use the park roads for an entire season was set at $7.50 and so remained until 1926 when it was reduced to $3.00.

By 1919 there had been some relaxation in the automobile regulations and a strict schedule of departure and arrival was not required. On steep grades speeds up to 12 miles per hour ascending and 10 when descending were permitted, the maximum approaching sharp curves was 8 miles per hour, and in 1916 "on good roads with straight stretches, and when no team is nearer than 200 yards, the speed may be increased up to 20 miles per hour." In 1919 this top speed was increased to 25 miles per hour, and is now up to 45 miles per hour.

In contrast to 1915, 406,077 motor cars and motorcycles were checked into Yellowstone National Park in 1952 carrying 1,350,295 people.

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