GOSA TRANSACTIONS

The Journal of

The Geyser Observation and Study Association

Volume III
1992

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Volume III
Published June 1992

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The price of each issue is set separately according to size and in keeping with GOSA's non-profit goals. The set price of this issue is $15.00 to the membership of GOSA and $27.50 to non–members, agencies and institutions.

Cover Photograph:

An eruption of Morning Geyser, Lower Geyser Basin, Yellowstone National Park, Wyoming during the remarkable activity of August, 1991. Photograph by Lynn Stephens.

Printed By:

B&J Printing
Apple Valley, California

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Yellowstone Geysers Known Active in 1990

compilations by T. Scott Bryan

On the following pages are separate listings of the Yellowstone geysers known by observation to have been active during 1990 and 1991. Although much of the information is based on my personal observations, the complete list reflects as it always does the work of many individuals ranging from the members of GOSA, to the Park interpretive staff, to the Park Research Geologist.

These listings make no claim as to completeness. I personally was able to spend somewhat less time in Yellowstone during both of these years, and there are almost unquestionably additional observations that were never passed along to me. Also, a number of lesser, remote thermal areas were either not or only briefly visited. Accordingly, the numbers of geysers cited here should be taken as minimal.

The list is organized geographically by geyser basin, and then by recognized spring group within each basin. When applicable, the springs are then listed in an along–the–trail order. The overall organization thus is the same as used in my book, *The Geysers of Yellowstone*, which also contains the informal "UNNG" designations.

The total numbers of recorded observed active geysers in these years was:

Area	1989	1990
Upper Geyser Basin	198	193
Midway Geyser Basin	23	22
Lower Geyser Basin	124	111
Norris Geyser Basin	37	38
Gibbon Geyser Basin	11	14
West Thumb Geyser Basin	11	11
Lone Star Geyser Basin	9	10
Shoshone Geyser Basin	42	49
Heart Lake Geyser Basin	33	≈30
Minor Backcountry Areas	4	7
Total Number of Observed Geysers	**492**	**485**

Geysers Known Active, 1990
Yellowstone National Park

Upper Geyser Basin

Old Faithful Group— 3 geysers

Old Faithful
OFG-1 ("Teapot")
OFG-2 ("new", reported by Hutchinson)

Geyser Hill Group— 47 geysers

Bronze Spring
Silver Spring
Little Squirt
North (Big) Anemone
South (Little) Anemone
Plume
GHG-2 ("Ballcap" [drop name])
UNNG near GHG-2
Beehive
Beehive's Indicator
"Beehive's 2nd Indicator(s)"
UNNG above Copper Kettle
Depression
GHG-3 (9 independent vents)
Little Cub
Lion
North Goggles (rare, minor)
UNNG across from Lion
GHG-5
Beach Geyser (GHG-6)
GHG-7
Aurum
UNNG north of Doublet Pool
UNNG south of Doublet Pool
Pump
Sponge
Slot (?name)
Vault
Giantess
Infant
Dome
Butterfly Spring
Peanut Pool
Mottled Spring
Model
UNNG near Model
Roof
GHG-9 ("Borah Peak")
Solitary

Castle Group— 10 geysers

Castle
"Gizmo"
UNNG independent vent near Gizmo
Tilt
Crested Pool
Sprinkler
Terra Cotta vent 'A'
Terra Cotta vent 'B'
Terra Cotta vent 'C'
Terra Cotta vent 'D'

Sawmill Group— 13 geysers

Deleted Teakettle
Churn
Sawmill
Uncertain
Tardy
CGG-1 ("Twilight Spring")
Penta
Spasmodic
Oval Pool (2 vents)
UNNG below Old Tardy ("Nifty")
Old Tardy
Crystal's Vent ("Slurp")
UNNG near Frog Pond

Grand Group— 18 geysers

Bulger
Rift
West Triplet
East Triplet (minor, with "Sputniks")
"Sputnik Complex"
Percolator
Grand
Turban
Vent
UNNG "Bush" geyser area
Witches Cauldron (near steady)
Lime Kiln Spring (near steady)
UNNG Orange Spring Gp. (5)

Giant Group— 8 geysers

Oblong Giant Mastiff	Catfish Bijou UNNG "Platform Geysers" (counting as two geysers)	UNNG behind Bijou (several vents, all? independent geysers

Round Spring Group— 5 geysers

Round Spring West Round Spring	RSG-1 RSG-2	Pear Geyser

Daisy Group— 9 geysers

Bank DSG-1 Radiator (subterranean)	Bonita Pool's sputs Daisy Comet	Brilliant Pool Splendid (1 eruption, 5/27/90) Pyramid

Punch Bowl Group— 3 geysers

PBG-1	PBG-2	UNNG adjacent Punch Bowl

Grotto Group, w/ Riverside— 10 geysers

Grotto "Central Vents" Rocket	Grotto Fountain South Grotto Fountain UNNG ("S. S. Grotto Fountain")	Spa UNNG ("Variable Spr" [?spouter]) UNNG ("Marathon Spring") Riverside

Chain Lakes Group— 3 geysers

Square Spring	UNNG behind Square Spring	Link (minor)

Morning Glory Group— 4 geysers

Fan Mortar	East Sentinel	West Sentinel

Cascade Group— 6 geysers

Artemisia Atomizer	"Slide" UNNG above Slide (new, 5/90)	Sprite Spring Seismic (single, to ≈15 feet, 5/30)

"Westside Group"— 5 geysers

Ouzel WSG-1 ("Sideshot")	WSG-2 ("Bigfoot") WSG-5	YM-210 ("South Pool")

"Old Road Group"— 8 geysers

UNNG west of Biscuit Basin Geyser
ORG-1
ORG-2
Cauliflower
ORG-4 ("Mercury/Mercuric")
ORG-5 (in Cauliflower runoff)
Rusty
UNNG ("Dusty" [1990 winter only])

Biscuit Basin (Soda Group)— 15 geysers

Jewel
Shell Spring
Silver Globe 'A' ("Cave")
Silver Globe 'B' (Spring, north vent)
Silver Globe 'C' (Spring, south vent)
Silver Globe 'D'
Silver Globe 'Slit'
UNNG bet. Silver Globes and Avoca
Avoca
East Mustard Spring
UNNG first spring north of boardwalk
UNNG farther from boardwalk
Coral (subterranean)
Fumarole
UNNG west of Sapphire Pool (subt.)

Black Sand Basin— 12 geysers

Whistle
The Growler
Spouter
Ragged Spring
"Ragged Spring's Annex"
UNNG east of Green Spring
Green Spring (minor, and as int. spr.)
Cliff
Handkerchief Geyser
UNNG near boardwalk
UNNG within steep bank of stream
Sunset Lake

Pine Springs Group— 2 geysers

PSG-1 (the deep hole)
PSG-2 (?Mud Spring)

Myriad Group— 9 geysers

Three Crater Geyser
"Mugwump" (name pending)
UNNG southeast of Three sisters
UNNG near Bell Geyser/Spring
Strata (minor, subterranean)
White
Lactose Pool
Spectacle (minor)
Round

Pipeline Meadows Group— 3 geysers

PMG-1 ("Dilapidated")
PMG-2
PMG-3 ("Pipeline Meadows G.")

Total Observed Active Geysers, Upper Geyser Basin, 1990 = 193

Midway Geyser Basin

Rabbit Creek Valley— 3 geysers

Rabbit Creek Geyser
UNNG near Rabbit Creek Geyser
Paperiello #11

Egeria Springs— 10 geysers

Till
UNNG northeast of Till
MGB-1
MGB-3
UNNG near MGB-3
Silent Pool
Pebble Spring
River Spouter
MGB-4
"New" Catfish

"Main" Area— 9 geysers (very minimal)

Flood	West Flood	UNNG on flat (5 minimum)
UNNG ("Tangent")	UNNG on bank downstream W. Flood	

Total Observed Active Geysers, Midway Geyser Basin, 1990 = 22

Lower Geyser Basin

Great Fountain and White Creek Groups— 11 geysers

Great Fountain	WCG-5 (near A-2)	WCG-3 ("Tuft" or "Crescent")
GFG-1 ("Shrimp/Prawn")	WCG-2 ("Logbridge")	Spindle
WCG-1 ("A-0")	Botryoidal Spring	UNNG near Spindle
A-2		

White Dome and Tangled Creek Groups— 6 geysers

White Dome	Crack	UNNG ("Cave Spring")
Gemini	Pebble	WDG-1

Pink Cone Group— 8 geysers

Pink Cone	Bead	Labial
Pink	Box Spring	Labial's West Satellite
Narcissus		Labial's East Satellite

Black Warrior (Firehole Lake) Group— 3 geysers

Young Hopeful	Gray Bulger	Artesia

Fountain Group— 13 geysers, Pithole, Fissure, and Gore areas not observed)

FTN-1	FTN-2 ("Super Frying Pan")	New Bellefontaine
UNNG near Twig ("Bearclaw")	Sub	FTN-3
Twig	Spasm	UNNG west of FTN-3
Jet	Clepsydra	Bellefontaine
Fountain		

Kaleidoscope Group— 14 geysers

Kaleidoscope	Honeycomb	UNNG (8 minimum)
Blowout Spring	Honey's Vent	
Deep Blue	"Firehose"	

Sprinkler Group— 16 geysers

West Sprinkler
Angle
UNNG ("Vertical")
Impatient Miser
Earthquake (minor)
Bridge
UNNG (10 minimum)

Thud (Hotel) Group— 2 geysers

THD-1
Kidney Spring

Culex Basin, Morning Mist Group, and Quagmire Group— 10 geysers

Geyserlet
UNNG ner Geyserlet
Morning Mist
UNNG Culex Basin (4 geysers)
UNNG Quagmire Group (3 geysers)

River Group— 14 geysers

RVG-4 near Azure Spring
UNNG near RVG-4
Pocket
UNNG pool at N of Upper East Area
"Upper East Area" (3 geysers)
Conch/Fortress
UNNG north of Armored Spring
UNNG ("Brain")
UNNG ("Blurple")
Mound
UNNG adjacent to Mound
RVG-1

Fairy Creek and Fairy Meadows Groups— 10 geysers

Column Pool
Locomotive
UNNG Fairy Meadows Group (2 g.)
UNNG Fairy Creek Gp (6 g. min.)

Sentinel Meadows Group— 3 geysers (briefly visited)

Iron Pot (inferred from appearances)
SMG-2
UNNG Paperiello #11

Imperial Group— 1 geyser

Spray

Total Observed Active Geysers, Lower Geyser Basin, 1990 = 111

Norris Geyser Basin

Porcelain Basin— 19 geysers, +8 geysering vents in Porcelain Terrace vicinity

Guardian
Valentine
UNNG near Valentine
Dark Cavern
UNNG below Ledge
Arsenic
Lava Pool Complex (1 vent observed)
UNNG northeast of Constant
Fireball
Fan
UNNG south of Little Whirligig
Little Whirligig
Constant
Whirligig
Splutter Pot
UNNG east of Pinwheel
Blue
Incline
UNNG north of Incline

Back (Tantalus) Basin— 19 geysers

Steamboat	"Son of Green Dragon Spring"	Veteran
Echinus	Orbicular (Orby)	Corporal (*very* minor)
Puff-n-Stuff	Dabble	Rubble (1 minor observed)
Big Alcove Spring	UNNG near Double Bulger	Palpitator Spring
Medusa Spring	Porkchop (minor, boiling)	Minute
UNNG Muddy Sneaker Complex	Vixen	UNNG ("Rediscovered")
		UNNG 200m NNW of Crackerjack Sp

Total Observed Active Geysers, Norris Geyser Basin, 1990 = 38

Gibbon Geyser Basin

Artists Paint Pots— 1 geyser

GIB-2

Geyser Creek Springs— 13 geysers

UNNG ("Anthill"/"Formicary")	UNNG ("Oblique's Jet")	Subterranean Blue Mud Geyser
UNNG lower flat	Big Bowl	Tiny
Oblique	UNNG north of Big Bowl	Bat Pool
		UNNG (4 observed)

Gibbon Hill Group and vicinity— 0 geysers; Gibbon Hill Geyser "extinct" due to landslide debris, one near geyser in hot spring area to north

Total Observed Geysers, Gibbon Geyser Basin, 1990 = 14

West Thumb Geyser Basin

Main (Upper) Group— 4 geysers

Surging Spring	Ledge Spring	Percolating Spring
		UNNG small on side of Fishing Cone

Lake Shore Group— 4 geysers

Occasional	Lone Pine	Overhanging
		Blowhole Spring

Potts Basin— 3 geysers observed from Grand Loop Road overlook

Total Observed Geysers, West Thumb Geyser Basin, 1990 = 11

Lone Star Geyser Basin

Lone Star Group— 3 geysers

Lone Star	LST-1 ("Black Hole")	LST-2 ("Perforated Mound")

"Channel Group"— 3 geysers

LST-3	UNNG near LST-3	LST-4

"Campsite (Stream) Group"— 3 geysers

LST-5	LST-7	UNNG multiple vents near LST-7

Basset Group— 1 geyser

Buried

Total Observed Active Geysers, Lone Star Geyser Basin, 1990 = 10

Shoshone Geyser Basin

Little Giant Group— 6 geysers

Trailside	Double	Locomotive
Little Giant (minor)	Meander	UNNG USGS #11

Minute Man Group— 11 geysers

Soap Kettle	Shield	UNNG USGS #12
Little Bulger	Minute Man	UNNG USGS #16
"Little Bulger's Parasite"	"Minute Man's Pool"	UNNG USGS #21
Gourd		UNNG USGS #22

North Group— 16 geysers

Fissure Spring	Glen Spring (minor)	Frill Spring
UNNG USGS #61a	UNNG vent in northwest of Glen crater	Pearl Spring
UNNG USGS #62	Velvet	UNNG near Lion (original Lion?)
Yellow Sponge	Knobby	Bronze (minor)
Brown Sponge	Small	Iron Conch
	Mangled Crater Spring	

South Group— 3 geysers

Blue Glass Spring	SHO-8 ("Outbreak")	UNNG vent within Coral Spring

Orion Group— 2 geysers, both unnamed

Camp Group— 3 geysers

Geyser Cone	UNNG USGS #119 (?)	UNNG vent near USGS #121

Western (Fall Creek) Group— 4 geysers

SHO-9 ("Pecten")	UNNG USGS #135a	Boiling Cauldron (1 vent) Boiling Spring

Yellows Crater Group— 1 geyser

UNNG USGS #110

Total Observed Active Geysers, Shoshone Geyser Basin, 1990 = 49

Heart Lake Geyser Basin

I received virtually no data about activity at Heart Lake during 1990; what reports I did receive were based on very cursory visits and reflected absolutely minimal numbers of geysers; indeed, adding all together and making some liberal identity correlations, I come to a total of only 14 geysers observed active during 1990. That is undoubtedly far too low, although there is evidence of a decline in Heart Lake activity over the past few years.

For purposes of enumeration:

Total Suspected Active Geysers, Heart Lake Geyser Basin, 1990 = ≈30

Other Yellowstone Areas

Grand Canyon of the Yellowstone — 3 geysers observed from Artists Point
7–Mile Hole Area — Safety Valve Geyser and one nearby UNNG = 2 geysers observed
Crater Hills — Crater Hills Geyser = 1 geyser observed
Unnamed Area west of Norris = 1 geyser observed (the blue pool)

Total Miscellaneous Other Known Active Geysers, 1990 = 7

GRAND TOTAL KNOWN ACTIVE GEYSERS, YELLOWSTONE NATIONAL PARK, 1990 = 485

REPORT ON GEYSER OBSERVATIONS 3-18 AUGUST, 1990

by: Ralph C. Taylor Jr.
and Brenda K. Taylor

1 ABSTRACT

This report describes the results of the authors' thermal observations from 3 August 1990 through 18 August 1990. The observations were made in Upper Geyser Basin, primarily on Geyser Hill and in Biscuit Basin, and at Norris Geyser Basin.

2 INTRODUCTION

This report describes our observations of geyser activity in Upper Geyser Basin and Norris Geyser Basin in August, 1990. This report contains all our observed data for the geysers described. Eruption times for the major geysers were also recorded in the Old Faithful Visitor Center logbook.

3 Discussion of Observations

This section discusses the geyser observations we made. The data section of this report lists the data by geyser group, generally moving from Geyser Hill toward the north. We concentrated our main efforts on Geyser Hill, and made another set of detailed observations in Biscuit Basin.

3.1 Geyser Hill

We spent most of our time on Geyser Hill. This report includes the results of our Geyser Hill observations other than those of Anemone Geyser. One of the authors is performing a multi-year study of Anemone geyser; the amount of Anemone Geyser data collected is too large to include here. The changes in the behavior of Anemone in 1990 are described in a separate report still to be written.

The tabular data contains daily observations of many other Geyser Hill features as well. We kept a daily log of notes made on at least one walk around Geyser Hill. These notes were made in the hope that some correlation to subsequent activity by Giantess Geyser may be possible. Unfortunately, Giantess Geyser did not erupt during our stay.

3.1.1 Plume Geyser

We observed the eruptions of Plume Geyser whenever we were on Geyser Hill. Although the Plume eruption times are recorded in the Visitor Center logbook, we include them here to greater precision and to record the number of bursts. We have not recorded the Plume Geyser durations, but have counted the number of separate bursts in each eruption. While we observed Plume Geyser there were invariably four or five bursts in each eruption. Landis [Landis 1988] noted that the intervals between bursts are nearly constant, and the durations are also nearly constant.

The form of the eruptions did not vary during our visit. Following an eruption, the water level in the crater is out of sight from the boardwalk. Several minutes before the next eruption, the water level slowly rises to a point about 15 cm below the sinter shield forming the crater. Between one and two minutes before an eruption, the water level reaches a knob of sinter on the northeast side of the main (western) vent. The level fluctuates slightly (about 1 cm), then suddenly rises to overflow. The overflow floods the runoff channel to a depth of several centimeters; a rush of water surges down the channel. The eruption takes the form of a sudden explosive burst through the doming and surging water. The height of the first three bursts was generally similar, usually 6 to 9 meters (estimated). These bursts lasted an estimated 10 to 25 seconds. The fourth burst was sometimes weaker than the first three, and often lasted noticeably longer. The fifth burst was sometimes absent, sometimes very weak (as little as one or two meters in height), and varied from a few seconds to 30 seconds in duration.

Plume's intervals for our 1990 observations averaged 30m39.9s for 107 closed intervals,

Report on Geyser Observations for 1990

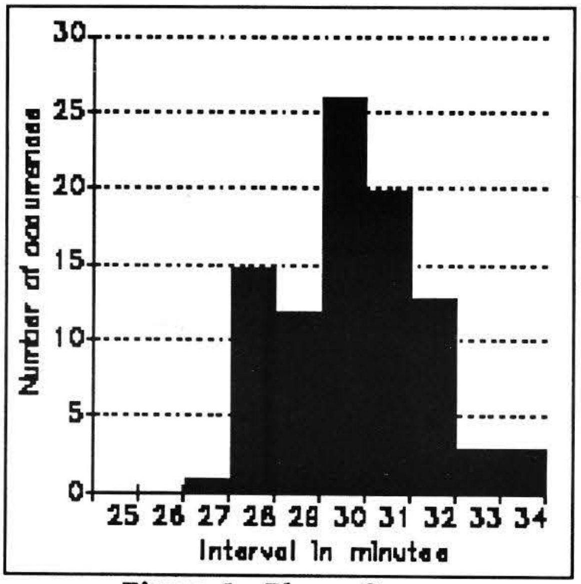


Figure 1 - Plume Geyser Eruption Intervals

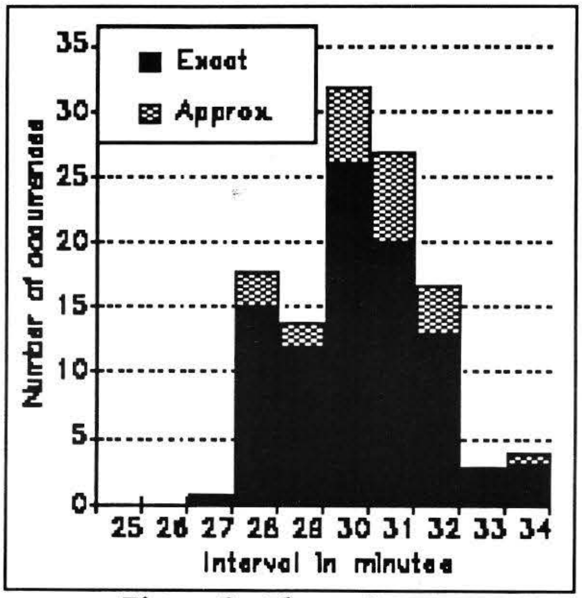


Figure 2 - Plume Geyser Eruption Intervals

6 of which were inferred. Based on our observations for 1988, 1989, and 1990, Plume's mean intervals appear to be lengthening [Taylor 1988], [Taylor 1989]. However, our 1989 data showed a significant shift in interval for five days during a Giantess eruption.

Year	Intervals	Mean Interval
1990	107	30m 39.9s
1989	116	29m 40.6s
1988	79	27m 12.5s
1989	56	31m 6.5s
1989	86*	28m 46.1s

* Giantess Geyser active

The significant shift in interval occurred between 1988 and 1989; the non-Giantess 1989 intervals were almost 30 seconds longer than those we observed in 1990.

Figure 1 shows the distribution of the observed eruption intervals. The graph includes only the intervals where both eruptions were observed closely. Some other intervals were observed from a distance and one or the other eruption was recorded to the nearest minute. The intervals before and after such an observation are marked approximate. Figure 2 includes both the exact intervals and the approximate intervals. The approximate intervals make little difference in the distribution.

Figure 3 shows the distribution of eruption intervals for our 1990 observations compared to the interval distribution for our 1989 data. The 1989 data appear to be shifted toward shorter intervals relative to the 1990 intervals. However, our 1989 intervals included four days of observations during an eruption sequence of Giantess Geyser.

Figure 4 compares the 1990 and 1989 interval distributions with the eruptions that coincided with the Giantess eruption removed. This chart shows no particular shift in distribution from 1989 to 1990; the distributions appear to match very closely. This suggests that the 1990 behavior has not

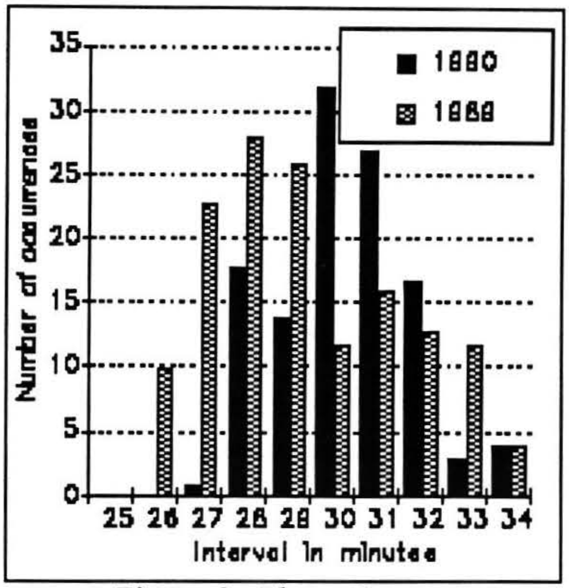


Figure 3 - Plume Geyser
1989 vs 1990 Interval Distribution

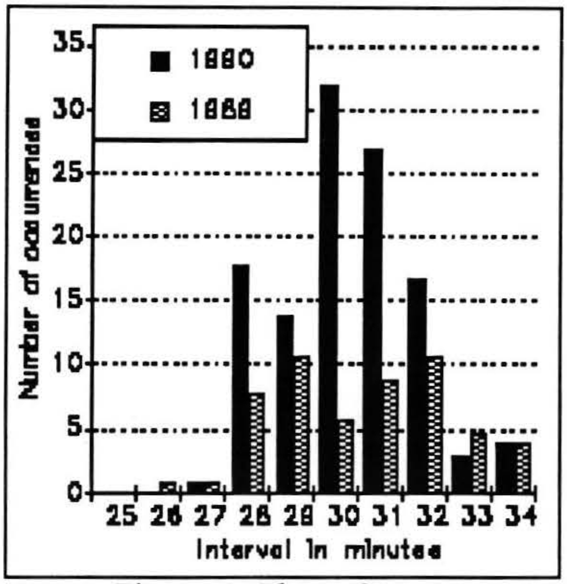


Figure 4 - Plume Geyser
1989 vs 1990 Interval Distribution

changed significantly from that in 1989.

Figure 5 and Table 1 show the mean intervals by date for our 1990 observations. The data show no significant day to day variation in the mean interval from day to day. The apparent dip in interval on 10 August results from a single interval observation.

During our observation of Plume Geyser, it appeared that there was often a long Plume geyser interval just before an eruption of Beehive Geyser. Examination of the Plume geyser intervals for several days for which we recorded consecutive intervals of Plume Geyser around the time of the Beehive eruption failed to show any definite correlation, however. Figures 6-9 show the Plume geyser intervals with the eruption time of Beehive Geyser marked.

Figure 6 shows the Plume Geyser intervals for 6 August 1990. There is a noticeable trend to increased intervals until the eruption just before the Beehive eruption. The Plume intervals drop from 34m to 28m at the Beehive eruption, then slowly recover to hover at 32m.

Figure 7 shows the Plume Geyser intervals for 9 August 90. Again, there is a clear increase in intervals from less than 29m to almost 32m, followed by a sharp drop to just over 28m at the Beehive eruption, followed by a recovery to 33m following the Beehive eruption.

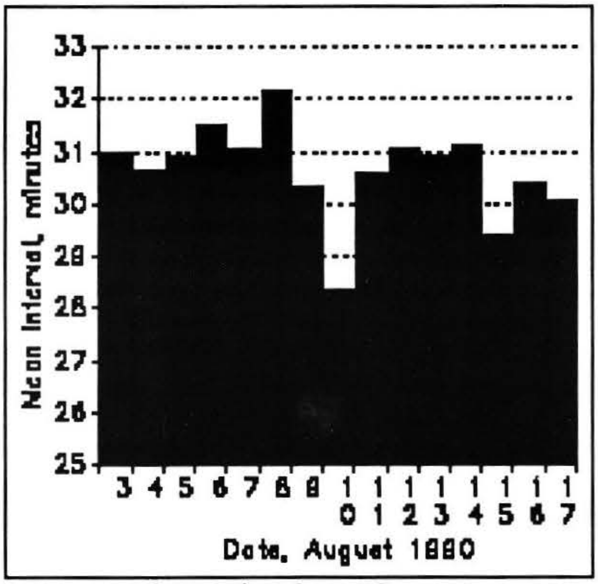


Figure 5 - Plume Geyser
Mean Eruption Intervals by Date

Report on Geyser Observations for 1990

	Bursts		Interval	
	Mean	S.D.	Mean	S.D.
Friday, 3 August 1990	4.25	-.--	31:01.0	--:--.-
Saturday, 4 August 1990	4.33	0.50	30:45.0	01:42.0
Sunday, 5 August 1990	4.38	0.51	30:57.4	00:56.7
Monday, 6 August 1990	4.46	0.52	31:33.5	01:41.0
Tuesday, 7 August 1990	4.50	-.--	31:07.5	--:--.-
Wednesday, 8 August 1990	4.86	0.38	32:12.7	--:--.-
Thursday, 9 August 1990	4.38	0.51	30:21.6	01:17.0
Saturday, 11 August 1990	4.38	0.52	30:39.0	01:41.4
Sunday, 12 August 1990	4.44	0.53	30:39.6	01:15.0
Monday, 13 August 1990	4.80	0.45	30:57.0	01:22.2
Tuesday, 14 August 1990	4.00	-.--	31:10.5	--:--.-
Wednesday, 15 August 1990	4.25	0.45	29:29.2	01:25.6
Thursday, 16 August 1990	4.57	0.53	30:26.8	01:47.3
Friday, 17 August 1990	4.33	0.52	30:05.8	01:09.3

Table 1 - Plume Geyser Mean Intervals

On 11 August 90, however, the pattern changes, as is shown in Figure 8. The intervals peak at over 34m seven intervals before the Beehive eruption, then decline steadily until Beehive finally erupts. The next interval was one minute lower than the pre-Beehive interval.

Figure 9 shows the pattern on 15 August 90. The Plume intervals vary between 28m and 30m, with no clear trend before or after the Beehive eruption. There is a 4-hour gap in observations; following that the intervals had lengthened by about two minutes.

Based on these graphs and other observations not shown, we conclude that there is not a simple relationship between Plume intervals and Beehive eruptions. From the relatively small number of consecutive intervals recorded, it is not possible to draw

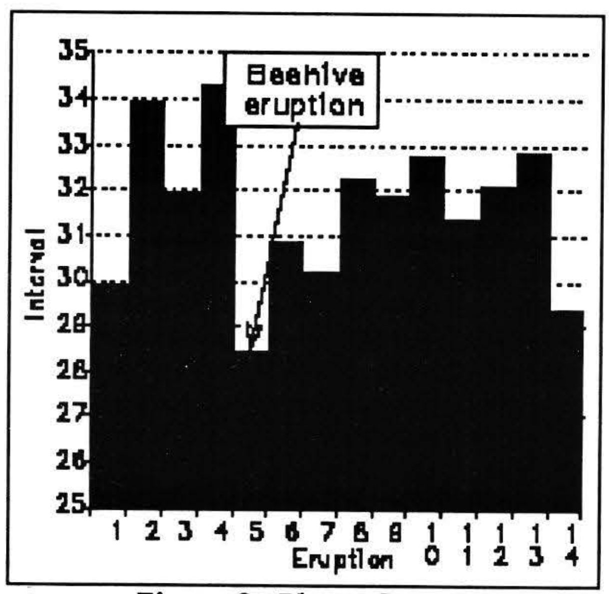


Figure 6 - Plume Geyser Eruption Intervals 6 Aug 90

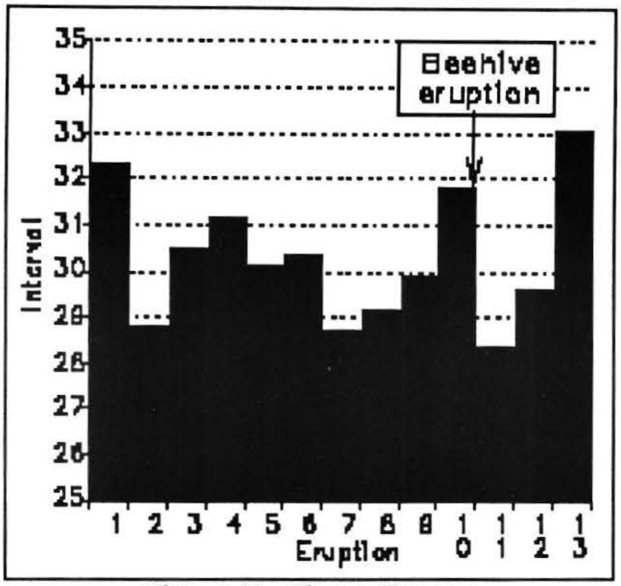


Figure 7 - Plume Geyser Eruption Intervals 9 Aug 90

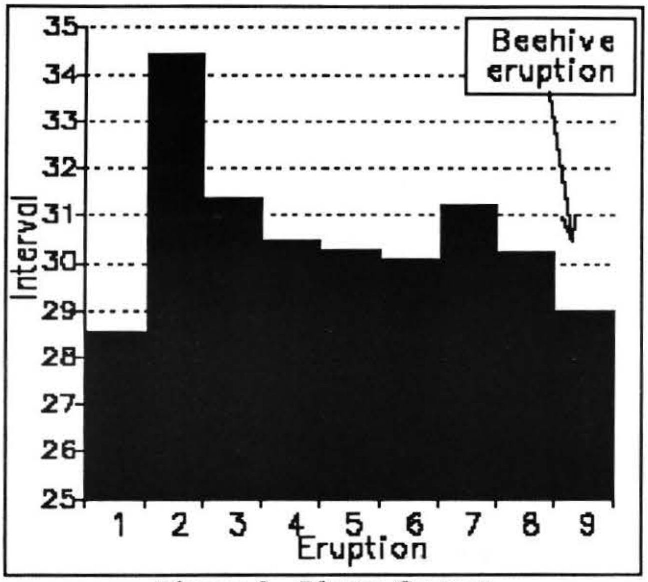


Figure 8 - Plume Geyser Eruption Intervals 11 Aug 90

firm conclusions about the pattern in Plume Geyser intervals. There is a variation of two to three minutes over about eight eruptions (about four hours). Since the variations are roughly one to two minutes, the recorded intervals in the logbook do not show the variations very clearly. A study of several days of precisely measured intervals might show a definite periodicity in Plume's intervals.

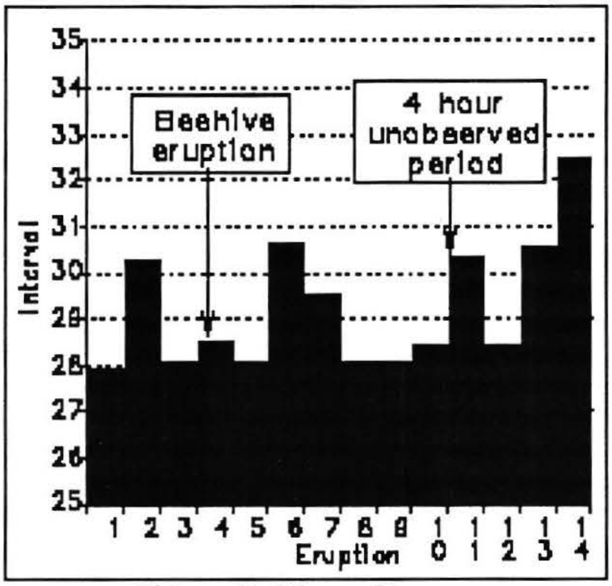


Figure 9 - Plume Geyser Eruption Intervals 15 Aug 90

3.1.2 UNNG-GHG-8 ("Borah Peak Geyser")

While waiting for Beehive Geyser and observing Plume Geyser's intervals, we recorded several sets of intervals on a small geyser across the boardwalk from Beehive. The geyser is approximately 25 meters northeast of Beehive Geyser. We believe this to be UNNG-GHG-8 in Bryan [Bryan 86]. As this geyser became active following the 1983 Borah Peak earthquake, it is sometimes referred to as "Borah Peak Geyser". The eruptions as observed from the boardwalk appeared to be about one meter in height.

Figures 10-15 are plots of the intervals and durations for the observed eruptions for August 6, 8, 9, 11, 12, and 13th, respectively. The observations span periods from about an hour on 6, 8, and 13 August to five hours on 9, 11, and 12 August. In all of the graphs the upper graph is the interval plot and the lower plot is the duration. A straight line curve fit is shown for each plot to show the trend of the data.

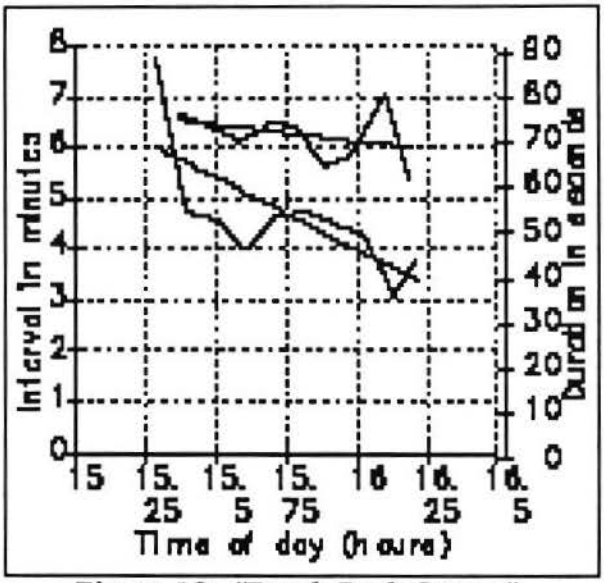


Figure 10 - "Borah Peak Geyser" Eruption Intervals and Durations 6 Aug 90

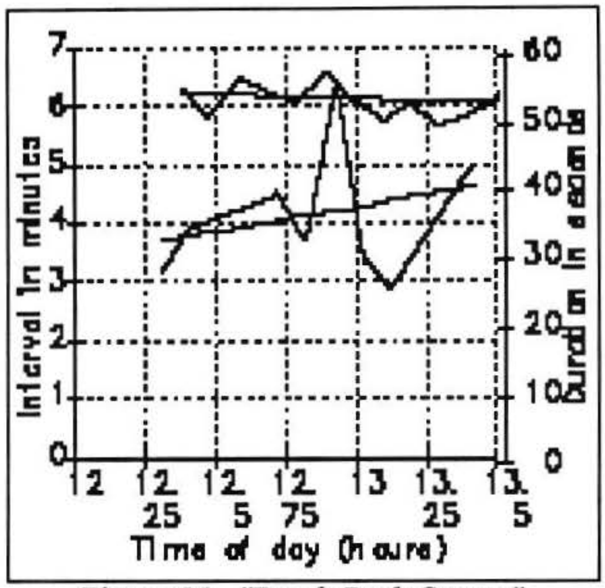


Figure 11 - "Borah Peak Geyser" Eruption Intervals and Durations 8 Aug 90

The graphs show a marked periodicity in both interval and duration. The intervals vary plus or minus one minute from an average near 6m30s. The period of the variation is approximately 30 minutes, giving two cycles per hour. The straight line on each graph is a linear curve fit to the data. This line shows the trend of the intervals. Over the longer periods of observation, the trend is essentially flat, suggesting that there

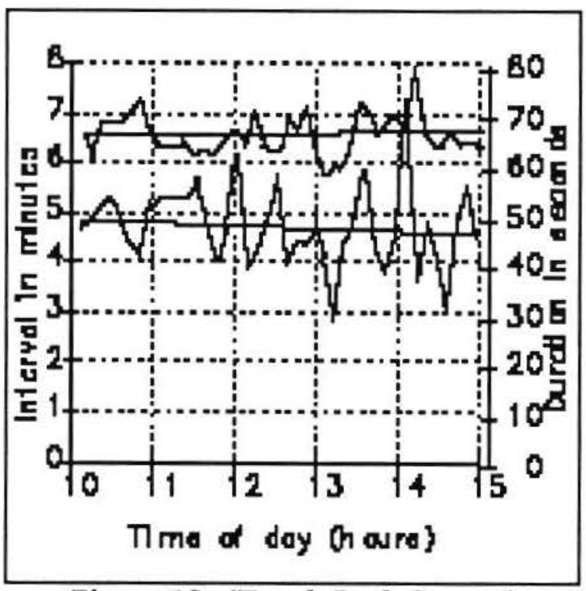


Figure 12 - "Borah Peak Geyser" Eruption Intervals and Durations 9 Aug 90

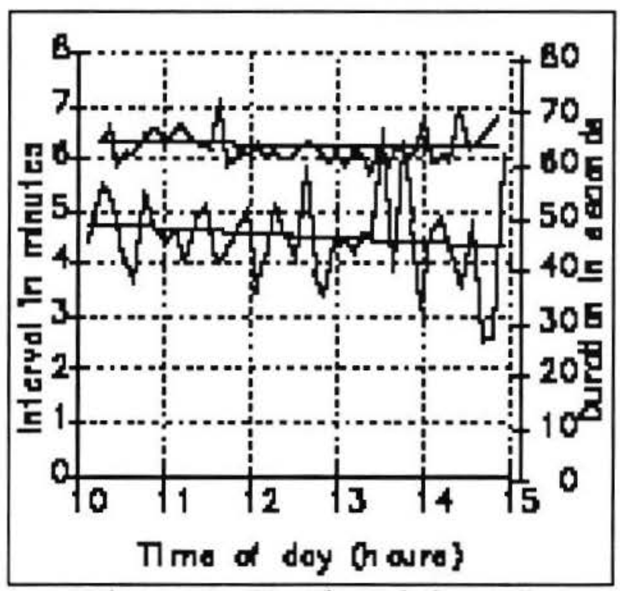


Figure 13 - "Borah Peak Geyser" Eruption Intervals and Durations 11 Aug 90

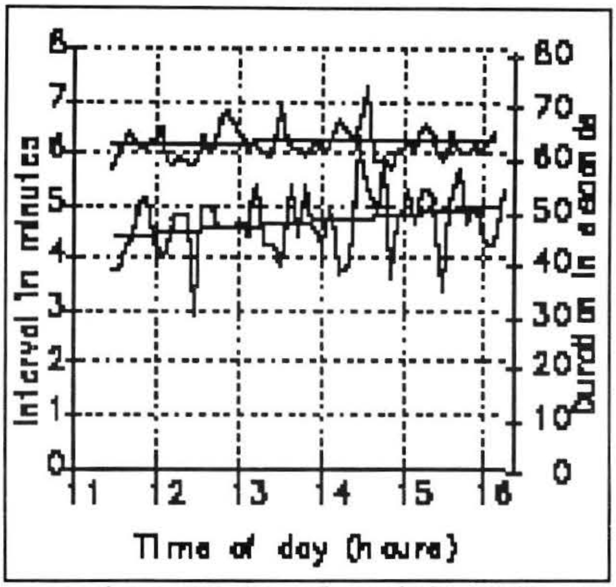


Figure 14 - "Borah Peak Geyser" Eruption Intervals and Durations 12 Aug 90

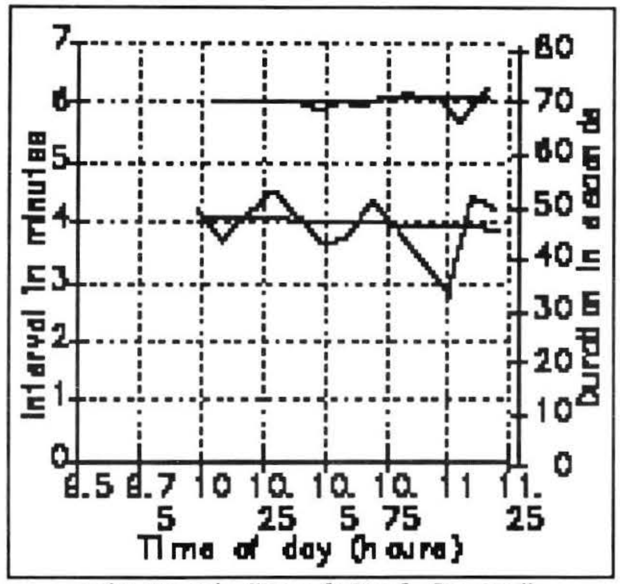


Figure 15 - "Borah Peak Geyser" Eruption Intervals and Durations 13 Aug 90

is little long term variation in intervals. Even over the relatively short periods of observation on 6, 8, and 13 August, the interval trend is nearly flat. Note that with intervals averaging 6m30s, the 30m period is not an alternation of long and short intervals, but a more gradual trend. The variation in interval is more pronounced in amplitude on 9 and 12 August, with intervals varying by over a minute. On 8, 12, and 13 August, by contrast, the amplitude of the variation is noticeably less, only 20s at times.

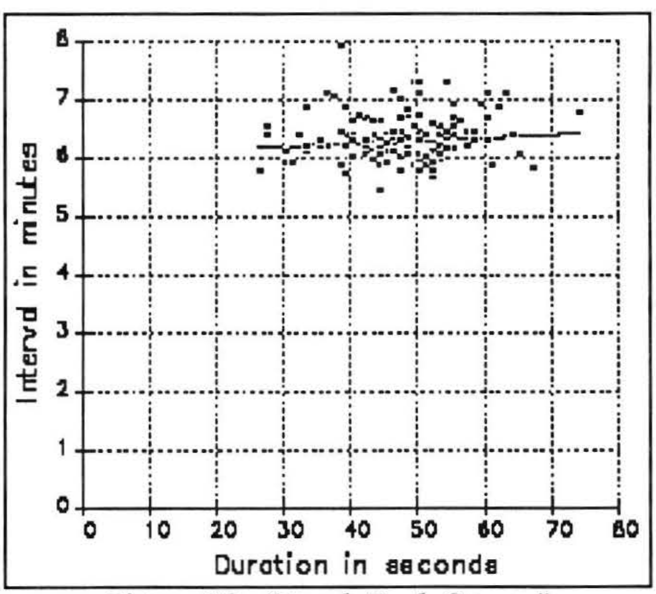


Figure 16 - "Borah Peak Geyser" Eruption Duration vs Interval

The durations exhibit periodic variation similar in form to that of the intervals. The magnitude of the variation and the trend in duration both are more pronounced than those for the intervals. Observed durations varied between 30 and 80 seconds, with most observations between 40 and 60 seconds. The trend lines for durations show more slope than those for intervals, even over five hours of observation. This may indicate a longer term variation in duration, although the trend is still very strong. The period of the short term variation in duration is 30m, similar to that of the intervals. The amplitude of the duration changes is roughly constant from day to day, with durations varying by 20s from 40s to 60s. The duration variation is not in phase with the variaticn in the intervals; indeed there is no obvious relationship between the interval and duration curves.

Figure 16 is a plot of interval as a function of the preceeding eruption duration. There is no apparent trend to the data, suggesting that the interval does not depend on the duration of the preceding eruption. This is further support for the independence of interval and duration suggested by the curves of interval and duration.

Our observations of UNNG-GHG-8 did not show any obvious relationship with Beehive Geyser or with Plume Geyser. The variation in both duration and interval at about two cycles per hour is relatively constant over the two week observation period.

3.1.3 Beehive Geyser

We spent a considerable fraction of our time watching Beehive Geyser and nearby features (many of these observations are described in the preceding sections). During our stay, Beehive was active and erupting on a 24+ hour schedule, occasionally skipping a day. We were seeking any correlation between Beehive and other phenomena in the area.

Besides the negative results described in the sections on Plume and Borah Peak geysers, we also observed the action of Beehive Geyser, Beehive's Indicator, and a small pool located to the West-Southwest of Beehive's cone. We heard of this pool from various other Geyser Gazers, who attributed the initial observation of the pool to Jens Day.

The "pressure pool" is located several meters west of Beehive's cone on a normally dry island in the runoff from Plume Geyser. We only observed the pool from the boardwalk, and therefore cannot give a good estimate of the size. It appears to be 10 to 15 cm in diameter, but there are no objects nearby to give scale. The pool can be observed best using binoculars standing on the boardwalk at a point nearest the Beehive Geyser sign. The pool is then visible just to the left of Beehive's cone.

The appearance of water in the "pressure pool" was a fairly reliable sign of an impending eruption of Beehive within a few hours. The usual behavior seen was for water to become visible in the pool an hour or so before the eruption. The water typically ebbed and rose, eventually beginning to surge and overflow.

On 16 August, a typical sequence of events occurred. The "pressure pool" began steaming at 1000 hrs. By 1045 the steaming stopped, but at 1132 water was halfway to the rim of the pool. Beehive's Indicator started at 1142, and Beehive followed at 1201. On 11 August a similar sequence occurred with the water appearing in the pool at 1340, about an hour before the Beehive eruption at 1436.

The "pressure pool" is not infallible, however. On 13 August, the pool was full at 0700 but the eruption did not occur until 1050. The "pressure pool" began bubbling at 1000 on that occasion.

On 12 August the pool filled at 1220, about 22 hours following the previous day's eruption. The pool remained full for several hours, but Beehive chose that day to skip an eruption. We noticed no occasions when Beehive erupted with no activity from the "pressure pool."

From these observations we conclude that the "pressure pool" indicates the relative activity in the Beehive system, and that Beehive demonstrates cyclic increases of pressure or water level with a 22 to 26 hour period. A peak of Beehive's water level does not necessarily mean that an eruption will ensue, but the activity peak appeared to occur whether or not the eruption occurred.

3.1.4 Bronze Spring and Little Squirt Geyser

Bronze Spring was quiet for most of our two-week stay at Old Faithful. On 4 August through 8 August Bronze Spring was well below the rim and quiet. On 8 August, however, the runoff channel from Bronze Spring was wet when observed at 1300. On

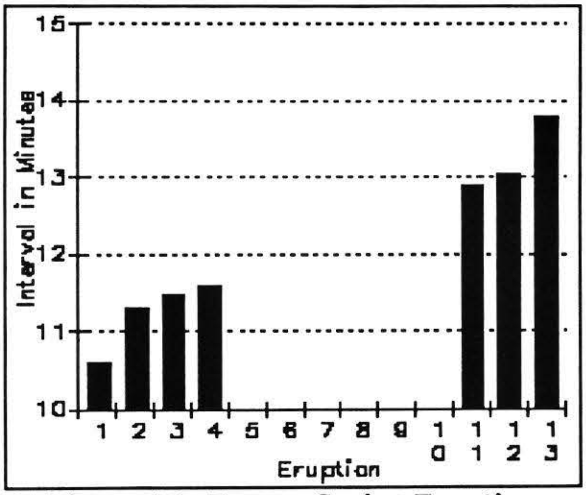


Figure 17 - Bronze Spring Eruption Intervals

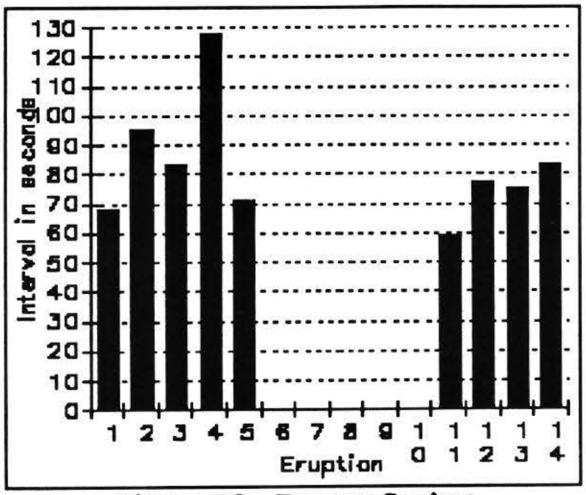


Figure 18 - Bronze Spring Eruption Durations

9 August through 11 August, Bronze Spring remained well below overflow and either completely quiet or had only slight bubbling. On 12 August, the water level was still 5 cm below the rim but more bubbling was evident along with surging of the water level. On 13 August the water was higher, just an estimated 2 cm below the rim with quiet bubbling. On 14 August, the water level was the same, but the spring was boiling vigorously.

On our daily walk around Geyser Hill on 15 August at 1020, the water in Bronze Spring was 15 cm below the rim and appeared turbid. Water was visible in the runoff channel. Evidently an eruption series had started sometime before 1020. The first eruption observed began at about 1021; the series continued until 1303 with a gap in observation between 1130 and 1222.

Figure 12 is a plot of the observed eruption intervals vs. the eruption number in the sequence. Figure 13 is a plot of the eruption duration vs. eruption number. The intervals increase steadily as the series progresses. There is a gap of six eruptions in the middle of the series when the author left to observe an eruption of Grand Geyser. The increasing intervals within the series is similar to the effect noted by the authors in 1989 in a series of eruptions of Giantess Geyser [Taylor 1989].

The Bronze Spring durations did not exhibit any apparent trend as the series progressed. All but one of the observed durations were between 70 and 95 seconds. The pattern of both intervals and durations differed significantly from the series we observed in 1989. The 1989 series had intervals of 6 to 8 minutes and durations ranging from 30 to 75 seconds, with the majority of the durations in the 60 to 65 second range. The 1989 intervals showed no trend to lengthening intervals during the series. We have no hypothesis to explain the change in behavior between 1989 and 1990. Of course, two observed series do not represent sufficient data to draw conclusions.

3.1.5 Other Geyser Hill Observations

The other Geyser Hill observations recorded in the data attached include isolated eruptions and short series of eruptions. Numerous eruptions of Depression and Aurum Geysers are included, all of which were recorded in the Visitor Center logbook. There are not enough closed intervals of either geyser to draw any conclusions.

Numerous Lion Geyser and Little Cub Geyser eruptions are noted. The intervals for Lion Geyser within a series were all close to 1h20m. The observed Little Cub Geyser intervals noted were generally 1h20m also.

A series of observations of Beehive's surges and indicator play is included for 16 August. The patterns of splashing do not appear to have any significant relationship to the subsequent eruption.

The authors made frequent tours of Geyser Hill, recording the state of various features. In general, we noted the status of Bronze and Silver Spring, Dome Geyser's runoff, Infant Geyser, the Giantess Geyser runoff channel on the geyserite slope ajacent to Teakettle Spring, Doublet Pool's overflow rate, and Copper Kettle's water level. All of these have been suggested as possible indicators of impending Giantess Geyser activity. We were not fortunate enough to see an eruption of Giantess Geyser, but present the data as possibly relevant when combined with other observations.

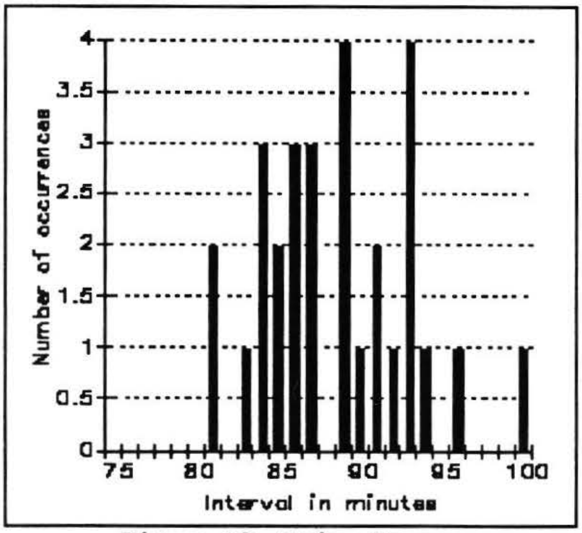


Figure 19 - Daisy Geyser Eruption Interval Distribution

3.2 Castle Group and Sawmill Group

We recorded numerous eruptions of Castle Geyser and Sawmill Geyser. The Castle Geyser eruptions were all logged in the Visitor Center log; the Sawmill Geyser eruptions were generally logged also.

3.3 Grand, Vent, and Turban Geysers

All of our observations of these geysers were entered into the Visitor Center logbook or duplicate observations reported elsewhere.

3.4 Daisy, Grotto, Artemisia, and Atomizer Geysers

The observations of these geysers were logged in the Visitor Center logbook in most cases. Many Daisy Geyser observations were made by sighting the steam cloud from Geyser Hill, and therefore may be as much as a minute later than the actual start of eruption. These times are only noted to the nearest minute. Figure 19 shows the distribution of the closed intervals of Daisy Geyser that are included in our observations. The observed intervals were fairly evenly distributed from 82 to 94 minutes with a mean interval of 88m33s.

Several eruptions of Grotto Fountain Geyser are recorded in the data. In all cases that we observed, eruptions of Grotto Geyser were preceded by the "pressure pool" a few meters west of Grotto Fountain Geyser filling and ebbing, with an eruption of Grotto Fountain Geyser occurring on one of the high water cycles. The eruptions of Grotto Fountain Geyser were strong in all observed instances. Durations ranged from 4m to over 20m. Grotto went into eruption between one and five minutes of the start of the Grotto Fountain Geyser eruption starts.

3.5 Biscuit Basin

We observed Jewel Geyser on three different days for three to six hours each day. We also observed the Silver Globe Geyser group for several hours on 7 Aug 90; the data and some analysis are presented here.

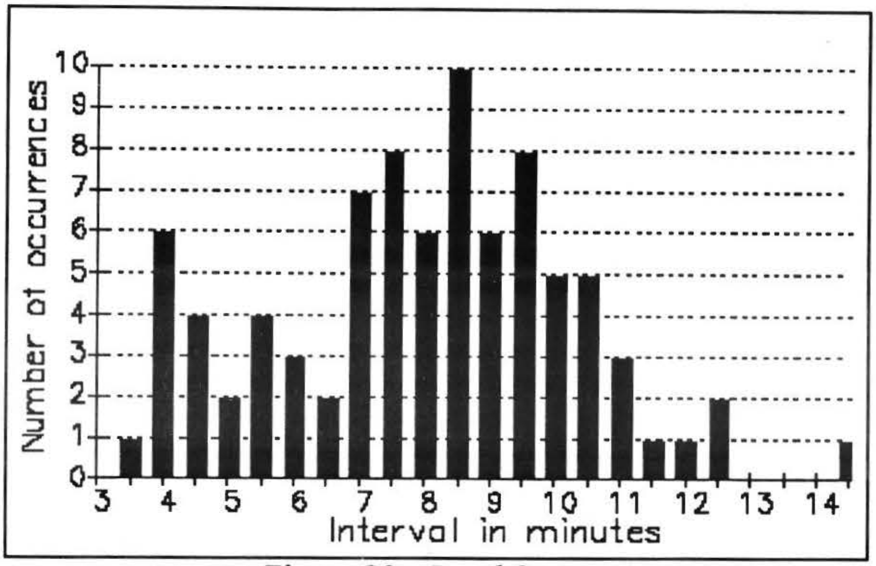


Figure 20 - Jewel Geyser Interval Distribution

3.5.1 Jewel Geyser

We observed Jewel Geyser for a total of 12 hours on three separate days; the observation periods ranged from 2h50m to 5h35m. Our data includes 85 closed intervals.

Jewel Geyser is situated at the crest of the rise of the boardwalk from the Biscuit Basin parking lot past Sapphire Pool and the junction of the boardwalk loop. The geyser erupts from a nearly circular sinter shield about 10 meters in diameter. There is an irregular crater in the form of a long narrow basin with the long axis running generally North to South. The inner part of the formation is a smooth appearing sinter mass surrounding the inner crater. The outer part of the sinter shield consists of sinter lumps and nodules, terminating in a ring of sinter sand. The outer portion of the sinter shield is convoluted and covered by small sinter knobs, perhaps the jewels for which the geyser was named.

Eruptions of Jewel Geyser followed a fixed pattern. The water gradually rose in the formation until the sinter nodules in the formation near the vent were nearly submerged. The water then welled up rapidly with a surging action. Shortly before the eruption began a distinct "plopping" sound was often audible from the boardwalk, apparently the result of an opening in the back (northwest) part of the crater being suddenly covered by waves. The water surged and domed over the vent, with some bubbling activity, for a minute or two before the start of the eruption. The eruption itself began with a sudden jet of water bursting upwards at an angle to the southwest.

Four kinds of bursts occurred. Most of the bursts were small, reaching 2-3 meters in height. The splashes from these bursts fell back into the pool of water around the vent. About a third of the remainder of the bursts were medium sized bursts that reached 3 to 4 meters and splashed the sinter around the vent. The medium bursts did not cross the prominent sinter mound to the west of the vent. The large bursts reached over 5 meters in height and splashed out of the inner formation, across the sinter mound, and to the edge of the sinter platform. A few bursts were even larger, clearing the edge of the sinter platform and extending well into the sinter gravel around the formation. These bursts are noted in the data as "H" for huge.

The bursts of an eruption are distinct, separated by several seconds. Typically the bursts last 5-6 seconds, rising and ending abruptly. The water in the crater remains high between bursts, welling up distinctly before each burst. We recorded the number of bursts in each eruption, the size of the bursts, and the total duration of the eruption. The duration is measured from the initial burst to the end of the last burst.

Figure 20 shows the distribution of the observed intervals. The distribution is bimodal

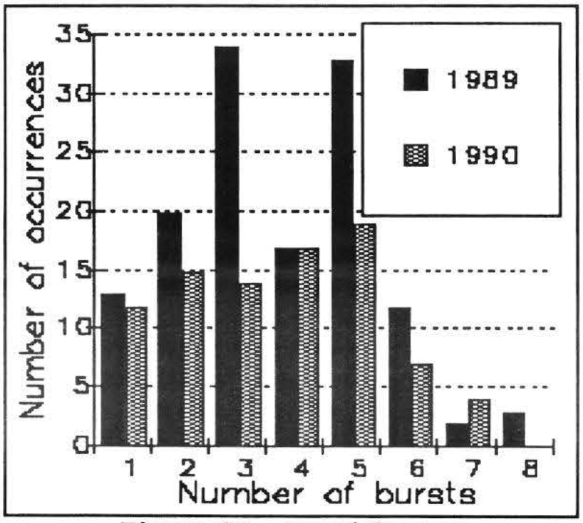


Figure 21 - Jewel Geyser Bursts Per Eruption

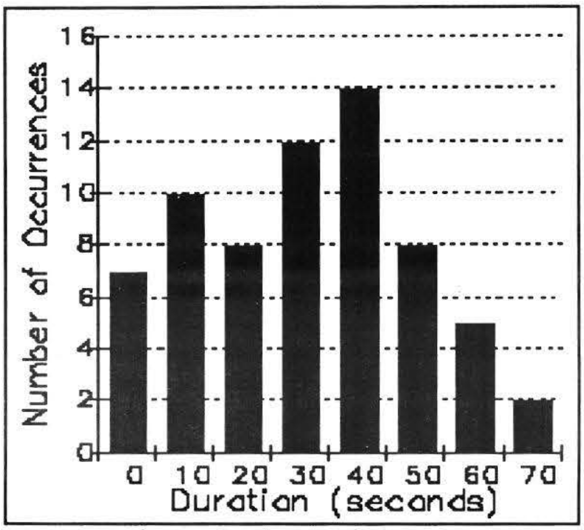


Figure 22 - Jewel Geyser Eruption Durations

with peaks at 4 min. and 8.5 min. The intervals ranged from 3m48s to 14m31s. This is a slightly wider variation than that reported earlier in [Bryan 1986] but similar to the distribution that we observed in 1989 [Taylor 89].

Figure 21 shows the distribution of the number of bursts per eruption. The burst distribution is similar to the 1989 distribution but the prominent peaks at three and five bursts are absent. Eruptions with six or seven bursts were relatively rare in both years. Bryan reports a range of 1-6 bursts, with two or three being most common. Our data show more bursts and longer intervals with a 9m average interval and most eruptions having between one and five bursts.

Figure 22 shows the distribution of the eruption durations. The histogram shows that the duration distribution is identical in shape to the distribution of the number of bursts per eruption. Durations are evenly distributed between five seconds and one minute.

In our 1989 report [Taylor 89] we described a relationship between the number of bursts in an eruption and the subsequent interval. Our 1989 data showed that the relationship between the burst count and the following interval is linear, and is described by the following equation:

$$I = 1.02 * B + 4.64$$

where:

I = predicted interval in minutes
B = number of bursts

During our 1990 observations we used the 1989 equation to predict when the next eruption would occur. The estimates were done by using the approximation of 4m40s plus 1 minute for each burst. The predictions were generally good within two minutes, or about 20%.

Figure 23 is a plot of our 1990 observations, plotting the intervals as a function of the number of bursts in the preceding eruption. The fitted straight line is also shown. Note that the fitted straight line fits the majority of the actual data points within two minutes.

Our 1990 data yields the equation:

$$I = 1.14 * B + 4.16$$

Compared with our 1989 data, the intervals were 30 seconds shorter at the intercept, but

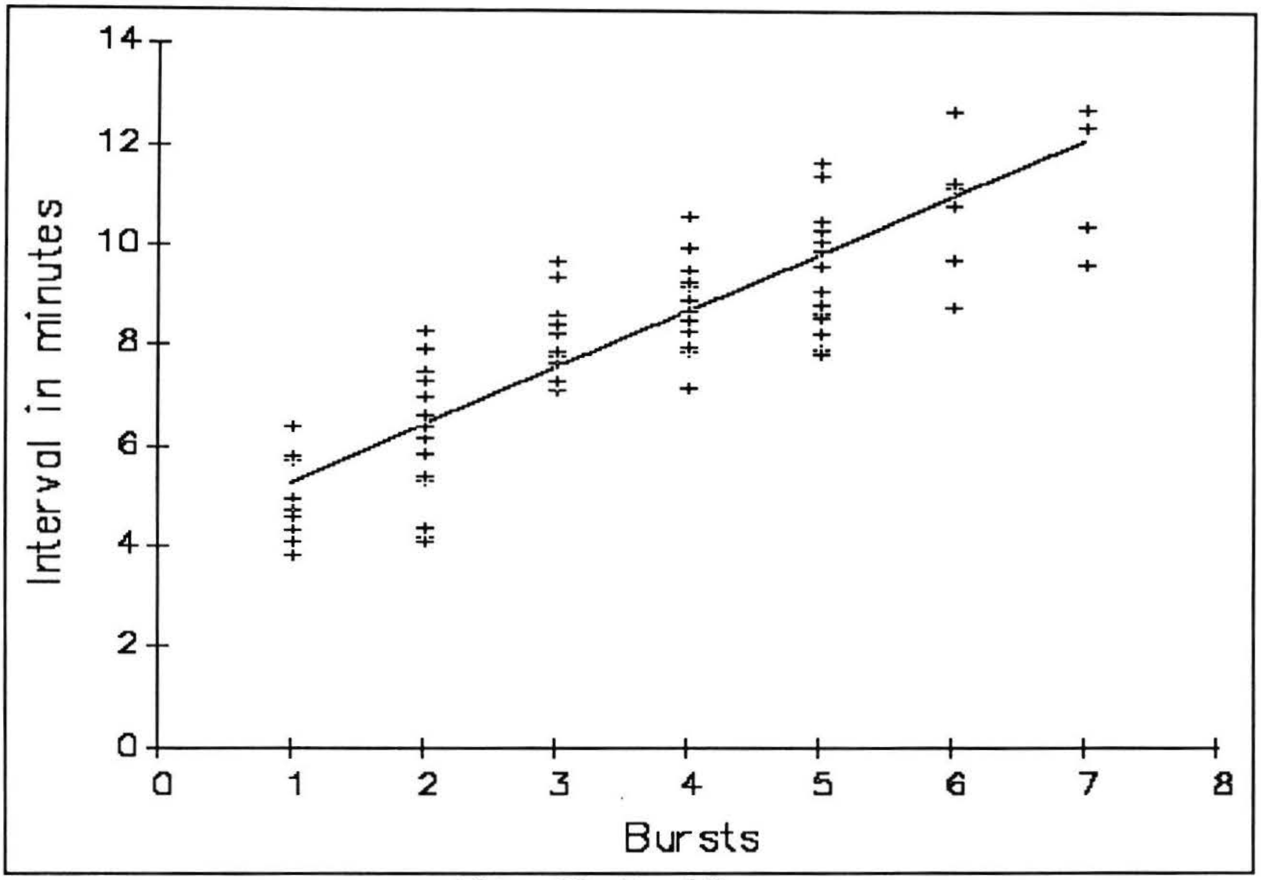


Figure 23 - Jewel Geyser
Burst Count vs Subsequent Interval

increased by 7 seconds more for each burst. That is, the slope of the least squares fit straight line is steeper. Generally, we conclude that the activity of Jewel Geyser is substantially the same as it was in 1989.

3.5.2 "Silver Globe Geyser"

On 7 August 1991 the authors recorded data on activity in the Silver Globe Geyser group for several hours. The collected data is included with this report.

Our data shows a pattern of increasing activity in the B or C vents (as described in Paperiello's map of Biscuit Basin.) Minor activity occurred every minute or so, with durations of five to 20 sec. Major eruptions, generally coinciding with eruptions of "Silver Globe Slit" geyser, occurred at approximately 20 minute intervals. The major eruptions were much stronger, reaching 2-3 meters and with longer durations (20-40 sec).

Vents B and C generally dominated, with Vent D occasionally having series of short, low (20-50 cm) eruptions. Major eruptions often coincided with an eruption of Vent A, the "Cave".

3.6 Lower Geyser Basin

On Monday, 13 August 1991 we visited the White Creek area of Lower Geyser Basin. We observed Tuft Geyser in eruption at 13:07, and recorded a series of eruptions of Spindle Geyser. Spindle had two larger eruptions, reaching an estimated height of 1.3 meters.

The rest of the eruptions were 30 to 50 cm in height. Durations were generally 60 to 80 seconds. The mean interval was 2m46s.

3.7 Norris Geyser Basin

On Saturday, 18 August 1991 we visited Norris Geyser Basin. We observed "Inclined Geyser" for an hour, noting many minor eruptions. Few of these reached to the old road embankment. Later in the day one of the authors observed some much larger eruptions, but no data was taken. Intevals between the frequent minor eruptions were about one minute, and durations were typically 45 sec.

We noted data on short series of eruptions of Minute Geyser, Corporal Geyser, and Veteran Geyser also.

Minute Geyser erupted with intervals around 20 minutes and durations of about 14 minutes. The first eruption that we witnessed had a much shorter 8m23s duration, followed by an interval of 14m41s.

The three Corporal Geyser eruptions had intervals of 30m and 22m, with durations of 5m20s, 1m30s, and 3m43s respectively.

Editorial Note:

The raw data used for the statistical computations in this report is available upon written request to the editor of the *GOSA Transactions*. This material totals about 30 pages.

The "Big Cub–Lioness–Beehive" Connection

by Rocco Paperiello

Abstract
Recent discoveries have added much to the known activity record of Big Cub and Lioness Geysers, and have revealed an apparent activity relationship between them and Beehive Geyser.

Eruptions of the Lioness and Big Cub Geysers have been very uncommon throughout the history of Yellowstone National Park, and even in those years when seen, the number of eruptions is often few. Specific recorded eruptions of the Lioness and Big Cub are very sparse. Table I is a year by year compilation.

Although the Big Cub and Lioness have been known to have independent eruptions, it has been observed that most often an eruption of the Lioness would be accompanied by an eruption of Big Cub. Most of the early guide books noted that they commonly erupted together. Those few references which get more specific usually have an eruption of the Lioness being preceded by an eruption of Big Cub.

The best year in modern times by far for the Lioness was 1947. From August 30 through September 25 of that year, there were 12 known eruptions of the Lioness. All of these eruptions were accompanied by eruptions of Big Cub; in fact, all of those directly witnessed were preceded by Big Cub by a minute or two.

Of the seven eruptions of Lioness and the eight of Big Cub recorded by Marler in 1952, Marler reported in his 1973 *Inventory* :

> [An] eruptive cycle of Lioness began on February 14, 1952. The activity was spread over a period of at least three days and possibly four. During this time I observed 7 eruptions of Lioness and 8 eruptions of Big Cub. Most of the eruptions took place concurrently. However, I did see eruptions of both geysers that were independent of each other.

Curiously, I can find no record of this data anywhere else, including Marler's own 1952 Annual Report!

But by far the most extraordinary observations ever recorded concerning the eruptions of Lioness and Big Cub also involved Beehive Geyser. In fact, these observations are so amazing, I find it even more incredible that the only place Marler ever recorded them was in his unpublished article "Are Yellowstone Geysers Declining in Activity?", dated September 17, 1947:

> With the reawakening on August 30 of the Lioness and Big Cub Geysers after thirty or forty years of rest [actually, 13 years], the rejuvenation on Geyser Hill would seem to be complete... Since the reawakening on August 30 (conditions about the cone furnished certain evidence this was the first activity), there have, to date, September 15, been eleven known eruptions of the Lioness and Big Cub. Markers placed at the cone indicate that these eleven eruptions are the total number since the initial activity on August 30. [One more eruption of Lioness and of Big Cub will have occurred by September 25, after Marler wrote the paper.]
>
> Of unusual interest in connection with the activity of the Lioness and the Big Cub has been the seemingly sympathetic response of the Beehive. During all of the daylight eruptions of the Lioness and the big Cub, the Beehive has played within fifteen to twenty minutes following their play. With but one exception, September 7, all of the eruptions of the Lioness and the Big Cub occurring at night have been accompanied by a night eruption of the Beehive. Further suggestion that this sympathetic functioning might be due to underground connections is found in that, previous to the August 30 activity of the Lioness and Big Cub and the Beehive, the Beehive had not been observed in action since July 23. Since the rejuvenation of the Lioness and Big Cub (17 days) there have been thirteen eruptions of the Beehive. [Four more eruptions of the Beehive will have occurred by September 25, after Marler wrote the paper.]

Reference

Marler, G.D., 1973, Inventory of Thermal Features of the Firehole river Geyser Basins...: National Technical Information Service (NTIS), Pub. No. PB–221 289, Washington, D.C.

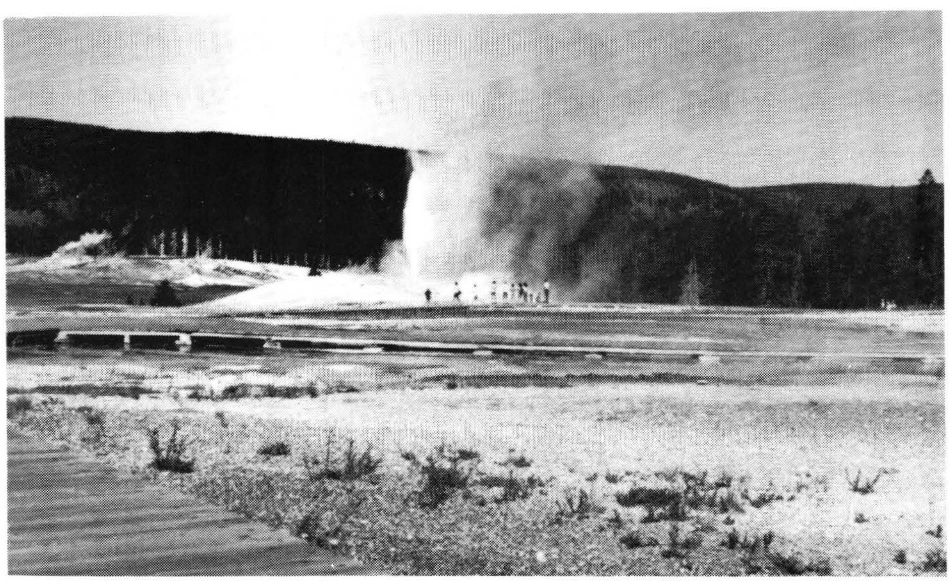
Table I

Presently Known Activity Record, Lioness and Big Cub Geysers

Year	Lioness	Big Cub	Reference	Notes
1873	1 eruption seen for a few minutes to 60'	1 eruption seen for 2 minutes, a major	Comstock	Big Cub preceeded Lioness by about 4 minutes
1877	active	no data	Norris	Name of Lioness given this year by Norris
1878	active "to a foot or two"		Peale	
1881	active	active	Norris, and Wylie	
1886	1 to 2 feet, and 1 to 5 feet		Weed	
1888	interval 1 to 10 hours duration 10 minutes	seen 5 or 6 times over season, to 70 feet for 15 minutes	Moody	
1893 *	interval irregular duration 10 minutes height 80 feet	no data	Wheeler	This same data is shown in the table in Guptill's guide book in his 1890, '93, and '94 editions.
1894	interval 1 to 2 days duration 12 minutes height 100 feet	no data	Wheeler	Next edition of Guptill (1896) again shows this change
1895	interval irregular duration 12 minutes height 100 feet	no data	Wheeler	Guptill's 1899 and 1900 books continue to show the OLD data
1901?	interval 1 to 4 days	no data	Guptill	Guptill's 1902 book reflects a change, possibly from 1901 data
1903?	1 eruption specifically noted	1 eruption to 30 feet specifically noted	Jack Haynes	played simultaneously with Lion and Little Cub
1907?	interval 15 to 20 days	no data	Guptill	Guptill's 1908 book reflects a change, possibly from 1907 data
1910	1 eruption recorded	no data	Interior	Government publication
(1911)	no eruptions		Interior	Government publication

1911	interval 15 to 20 days duration 10 minutes height 100 feet	no data	Jack Haynes	Note conflicting reports. In a letter to Hague, Haynes claimed this data to reflect 1911 activity
1912	1 eruption recorded	no data	Interior	Government publication
1914	1 eruption	no data	Interior	Government publication
1920	1 eruption (August 7)	1 eruption (August 7)	Interior	Report of Superintendent
1927	active	active	Phillips	"Slight" eruptions noted
1934	no data	1 eruption (December 7)	Childs	NPS report recently found by Paperiello
1947	12 eruptions	12 eruptions	Marler	Lioness followed Big Cub
1952	7 eruptions	8 eruptions	Marler	Most eruptions "concurrent", but a few of each independent
1987	no eruption	1 eruption (August 10) to 25 or 30 feet	Landis	See accompanying photograph

* Many of the guide books of the 1890s and early 1900s give varying information on Lioness and Big Cub concerning interval, duration, and height of eruptions. Specific changes for certain years almost certainly reflected changes in the activity seen during some previous season. A few of these changes which reflect probable observations are included here.



The Big Cub eruption of August 10, 1987, as viewed from near Sponge Geyser.
Photo by Phil Landis.

"Mugwump"

How and why the name was Applied to Three Crater Geyser Three Sisters Springs, Upper Geyser Basin, Yellowstone National Park

by Lee H. Whittlesey

Abstract

The curious name "Mugwump" was applied to a geyser of the Three Sisters Springs. The history behind the name is described, and an attempt to identify the modern spring is made.

History

In September of 1884, an election time, "while the air was full of politics" [Henderson, 1887], Yellowstone Park tour guide G.L. Henderson, a great giver of names, decided to give one more. He gave the name "Mugwump" Geyser to one of the erupting vents in present Three Sisters Springs in the Myriad Group of the Upper Geyser Basin.

"Mugwumps" in 1884 were "stalwart" republicans who refused to support their party's nominee James G. Blaine, voting instead for Grover Cleveland, the Democrat.

Henderson himself was a Blaine supporter, and it is evident from his name "Mugwump" that he, like others, considered the Mugwumps to be people who griped loudly for little or no reason. Shakespeare would have called it "much ado about nothing."

The story of the naming was told in three different places. We reproduce one here, with citations for the others. In September of 1884, Henderson conducted four ladies from Massachusetts...

> ...to the margin of a boiling lake called the Four Sisters [sic]. It was in reality one lake that narrowed and opened again at three places. In each of these sisters there was a gas-aqueous geyser that erupted in a succession of explosions like that of Chinese crackers or a well snapped whip. The most active of these geysers was situated near the south margin of the largest sister. The ladies stood close by admiring the calm mirror-like surface of the lake, with its beautifully ornamented and highly colored convoluted borders, the rim of which rose about three or four inches above the water.
>
> The ladies were suddenly startled by a succession of explosions, as the subterranean gasses arose like bluish flame as large as a palm leaf. Soon one lake was a seething caldron, being torn into shreds and tatters as the superheated globes burst hither and thither with rapidity and a deafening noise that prevented all conversation. Astonished and frightened, the ladies fell back to a safer distance, and when this gas-aqueous, pyrotechnic display terminated after about two minutes and a halt [?half], one of the ladies, wiping the steam from her glasses, said: 'Well, well! I should say that this was the clown of the geysers!' Another said: 'It is a splendid kicker anyway.' A third one added: 'It is a mugwump.' And so an anonymous geyser was named, and has since been crystallized into literature in the guide books, bulletin boards, and photographs of the park" [Anon., 1891; see also Henderson, 1887 and 1898a].

Thus from Henderson's experience in conveying visitors to Three Sisters Springs did the name "Mugwump" originate.

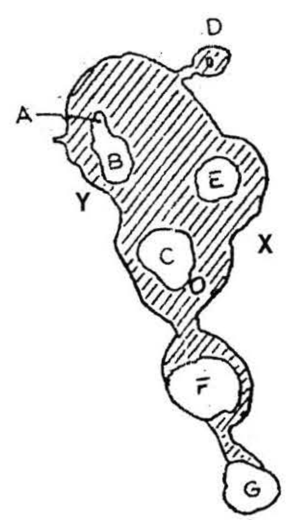
That the name was used as a kind of joke by park tour guides is evident from this account, probably from the summer of 1886:

> One [geyser]... must not pass unnoticed. Its very name will give it a peculiar charm for New England. It is known as the 'Mugwump'! I asked the superintendent why this name had been given it. His reply was: 'Wait until it goes off, then you will see.' Two hours later he shouted; 'Let's run over and see the Mugwump work!', and run we did with a will. 'Now wait and you will see why it received its name.'
>
> We waited. It was a spring some six feet in diameter. Clouds of steam began to rise; then came a thunderous, groaning roar, as if all the warring elements of the earth were about to burst forth. The waters began to rise as if to threaten our safety. The came the supreme effort, and amid groans and sobs a tiny stream of water rose six feet into the air. It trembled there for a brief moment, then fell, and all was still. Without speaking a word, our guide led us away. Each one was thus permitted to cherish his own thoughts and form his own conclusions [Gerrish, 1887].

Identity

From Henderson's several accounts, we glean that the name "Mugwump" was applied to one of the geysers/vents in Three Sisters Springs. But which one? There are two possibilities: the present Three Crater Geyser (Vent E on map) or Vent B to the northwest. Both vents are true geysers today.

The Three Sisters Springs
NPS map by Germeraad and Watson, 12/19/1959



Henderson's descriptions are not clear on his exact location: for one, he was confused about directions. His location in the 1898 account placed the geyser in the "south side of the largest" sister. The same location was used in the 1891 account: "near the south margin of the largest sister."

The problems here are: 1) what is the south side; and 2) which one is the largest sister?

Three Sisters Springs as a unit runs north and south. So, was Henderson's "south side of the largest sister" at point X or point Y (see map)? It makes a big difference, because Vent E is Three Crater Geyser and Vent B is the other erupting geyser. And what did Henderson mean by the "largest" of the "four" sisters? Did it include B and E; or C and E?

Likewise, there is a problem with another of Henderson's locations: "in the largest lake" [Henderson, 1902] does not tell us enough. But "the third one [of the four sisters], the turbulent geyser" [Anon., 1891] comes closest to giving us a good location. If the "third one" of the "Four Sisters" was Vents C and E (leaving Vent B alone logically for pool number 4), then the equation works and Vent E (Three Crater Geyser) is/was "Mugwump" Geyser. The other possibility is that the "third one" of the "Four Sisters" was Vent C alone, leaving Vents B and E as pool number 4; this is probably not the case, as Vent C has no history of erupting.

How about activity? Can we tell which vent was "Mugwump" from that? Henderson's geyser statistics do not help much: interval five minutes, duration 5-7 minutes [Henderson, 1898b]. In 1887, his statistics were: interval one minute, duration five minutes [Henderson, 1888]. If we go by today's activity, these statistics would more likely apply to Three Crater Geyser than to Vent B, and the 1878 statistics by Peale also more closely correspond to Three Crater Geyser than to Vent B. But we all know that things thermal can change, and it is Vent B that today makes the superior popping sound.

Activity of the two geysers today is somewhat different from that of Henderson's day. Three Crater Geyser today erupts at intervals of 5 to 60 minutes, to heights of 1 to 3 feet, and for durations of 1 to 5 minutes. Vent B, which did not erupt at all in Peale's day and apparently not in Henderson's day, either, erupts now at intervals of 15 to 45 minutes, to heights of 3 to 6 feet for 5 to 30 seconds duration [Paperiello and Wolf, 1991]. Furthermore, today Vent B erupts in series of two, separated by 45 to 60 seconds; and Three Crater Geyser is known to be affected by these eruptions (as well as by any other active Three Sisters Springs vents).

How about that sound? Can we tell which vent was Henderson's "Mugwump" from that?

Note the sound that Three Crater Geyser made in 1878 as described by Peale:

> d. *Three Crater Geyser.* This is towards the east side of the main basin, which here slopes to an orifice of about 2 feet diameter, from which the steam escapes and causes the spouting. The steam appears to escape with great effort, and makes a startling noise that is more like the noise made by a pack of fire-crackers muffled in a box than anything else I can think of. I raises the water in great bulges, splashing in all directions, with thumps. Every now and then a jet is squirted to a height of 15 or 20 feet, but the average is about 5 feet. The water in the main basin C and in B is thrown into waves, with beautiful effect, causing an overflow from the latter [Peale, 1878].

Henderson himself described the noises in several places. One description also gave a location of sorts:

> Mugwump [is] situated in the largest of the Four Sisters. The Mugwump is also evoluting as it is now discovered that a large quantity of its boiling water flows into the crater of the smallest Sister and is again boiled and discharged over and over again at the crater of the Mugwump with loud concussions like the reports of our Roman candles and fire crackers at our celebration on the 4th of July [Henderson, 1901].

Another description was:

> ...in the largest lake there is one crater, out of which arises, at intervals of about five minutes a bluish globe of gas which explodes with a noise like that of a Chinese firecracker, and some of them as loud as a pistol shot... [Henderson, 1902]

Today **both** geysers make the popping noise, Vent B more so than Three Crater Geyser. Paperiello notes that Vent B makes "a very rapid, obvious popping sound like muffled firecrackers." He has heard Three Crater Geyser popping too, but "only when it erupts ten feet high" rather than 1 to 3 feet; this was most recently in 1988.

So which vent was Henderson's "Mugwump"? If we were to go strictly by the popping noises, then Vent B would be "Mugwump", in which case this as a name would be valid. But Henderson's locations (even though they are not very specific) and the current activity of both geysers augers more (in the opinion of this writer) toward Three Crater Geyser being Henderson's "Mugwump." In this case, Henderson's name is one of interesting historical curiosity but of geographical invalidity.

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Major Geyser Activity in the Round Spring Group
Upper Geyser Basin, Yellowstone National Park, May 25-26, 1990
With An Historic Perspective

T. Scott Bryan

Abstract
Round Spring, a member of the Round Spring Group of Yellowstone's Upper Geyser Basin, underwent an unusual phase of eruptive activity on May 25-26, 1990. Details are recorded in this paper.

Introduction

On May 25, 1990 at 09:35, a group of geyser gazers awaiting an eruption of Grand Geyser observed an extraordinarily large and "out-of-place" steam cloud rising above the Round Spring Group. At first it was felt that the steam was simply a result of a wind eddy, since the day was very cold and windy, but the observation was repeated at 09:59 and at 10:20. On the latter occasion, one jet of water taller than the surrounding trees was clearly seen, corresponding to an eruption height of about 7 meters. Much stronger eruptions were seen later.

The source of the eruptions proved to be the original Round Spring (see explanation below), previously reported active as a geyser only during 1897 [Weed, 1897]. Most of the features of this group have been known to undergo geyser eruptions during past years. However, excepting the two small geysers designated as RSG-1 and RSG-2 [Bryan, 1986], all such action has been infrequent, brief, and relatively small. That numerous of the 1990 eruptions exceeded 10 meters in height and that at least one was clearly more than 15 meters tall is to say that these eruptions were the largest ever observed within the Round Spring Group.

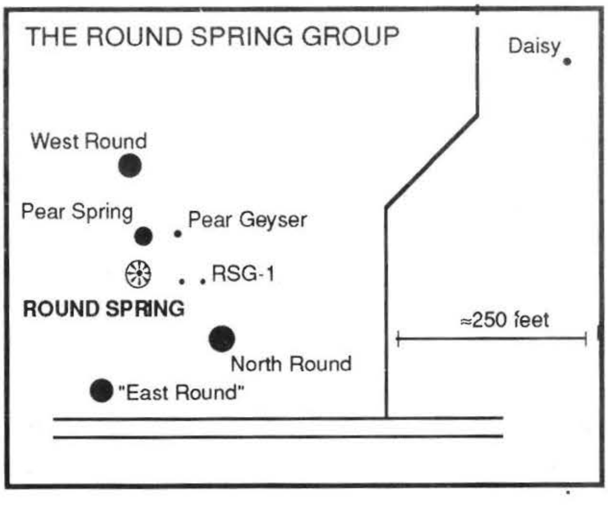
Spring Identities, Round Spring Group

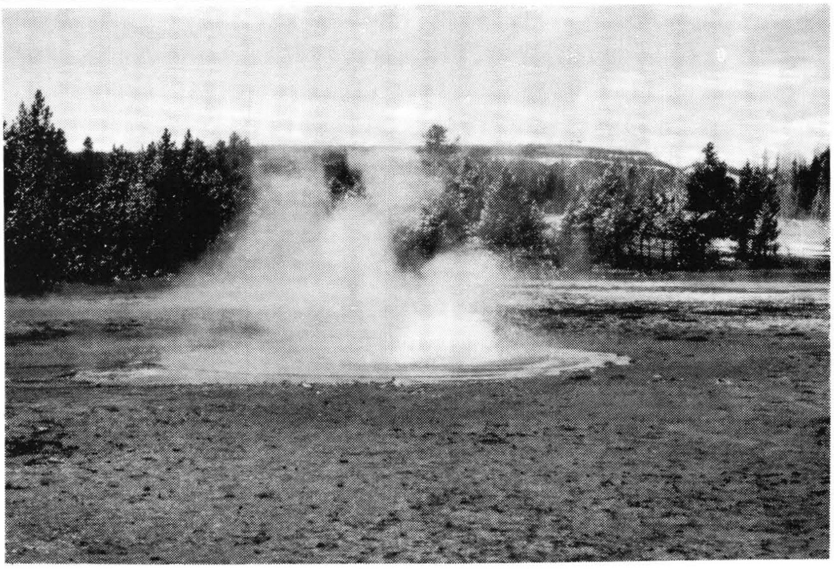
Only two of the features of the Round Spring Group were given formal names in the course of the early Yellowstone surveys. The identity of Pear Spring is clear because of the distinctive shape of its crater. The other, Round Spring, has had a more confused history.

Marler [1973] decided that Round was the perfectly circular pool closest to the paved trail, and therefore the easternmost spring of the group. This is an evident error. The original Round Spring, as designated by Peale [1878] and which is the feature that erupted during the 1990 episode, lies approximately 33 meters (110 feet) northwest of Marler's "Round Spring" [Whittlesey, 1988]. Note that Whittlesey himself errs in stating the direction as "southwest".

Because of this juxtaposition of names, for this report I have chosen to refer to the originally named feature as Round Spring, and I propose for Marler's feature the new designation of "East Round Spring."

Some of the remaining members of the Round Spring Group were also named by Marler, following after the original name. These are North Round Spring ("Trefoil Spring" of Weed), West Round Spring, and Pear Geyser. It is interesting to note that Marler did **not** apply a name to the original Round Spring, and that it is not described in his *Inventory*... [1973]! It is also worth noting that Round Spring is shown on the U.S.G.S. Thermal Map as a simple spring, with no eruptive record and no name. The location of all these features is shown on the map.





A major burst of Round Spring, May 25, 1990.
Photo by T. Scott Bryan.

Further clouding the issue is a "Round Spring Geyser." It apparently activated as a result of the 1959 earthquake and continued to play into 1961. But which feature is it? As of now, we really have no idea. Perhaps it is Round Spring itself, or RSG-1 or something else in the area; it definitely is not Pear Geyser. Note that the Round Spring Group as a whole was named not after Round Spring itself, but because the majority of its features are rounded in outline. "Round Spring Geyser" could be anything within the group.

The record of activity by these springs is spotty, but by extracting from Marler [1973], Whittlesey [1988], and numerous personal communciations and recollections, a record of activity among the Round Spring Group features was derived. As shown in Table 1, it indicates that geyser action has actually been widely distributed within the group, but that active episodes by any one feature have been rare.

The Eruptive Activity of May 25, 1990

The eruptive action by Round Spring was first observed at 09:35 on May 25. It is virtually certain that the spring had not erupted during the previous hour or so, or else its steam cloud surely would have been seen. It is, however, equally certain that there had been earlier eruptions, this judging by the state of washed areas and torn algae when the site was first visited at about 10:50; in fact, my judgement was that eruptions had likely been occurring for a day or more before they were discovered.

The pool was found to be very turbid (visibility was restricted to about 30 centimeters of depth), and it was surrounded by washed areas extending as far as 4 to 5 meters from the outer crater rim. These washed areas and the severly over-flown runoff channel were littered with sheets of algal mats as large as 60 centimeters in dimension. These mats were a bleached, whitish color, and without the typical "rotten fish" odor of freshly baked algae; this further implies that the initial eruptions had occurred some time before the activity was discovered.

The pool itself was constantly pulsating. Slight at most times, this became extreme (as large as 3 to 4 centimeters) and was accompanied by audible and feelable ground thumps near the time of an eruption. Near eruption times, also, the pool surface directly above the vent showed a slight superheated boiling (a temperature of 202°F was obtained a few hours later).

The eruptions proved to be of four types:

Splash: essentially single bursts; for record keeping purposes, only those taller than about 30 centimeters and isolated from larger eruptions were recorded;

Minor: eruptions consisting of a series of repeated bursts as much as 5 meters high and having a duration of 4 to 22 seconds;

Major: in most cases the culmination of an eruptive episode (see below); similar to the minor eruptions, but with durations between 32 and 67 seconds and heights reaching over 10 meters. Some majors consisted of two shorter plays separated by a distinct pause; for these, the total duration was recorded;

Great: observed just one time but clearly

TABLE 1

Historically Known Eruptive Activity

Round Spring Group

Round Spring	1897, to 5 feet 5/25-26/1990, frequent eruptions to >15m (this report)
"East Round Spring"	1940-42, uncommon, duration 3 minutes, height 20 feet (this spring?) 1951, active (no data)
North Round Spring	No eruptive record; "Trefoil Spring" of Weed
West Round Spring	1959, washed areas imply post-earthquake eruption(s) 1971, scattered episodes of frequent but brief eruptions to 15 feet reported by area naturalists 5/25/1990, two eruptions, each a single? splash to 1-2m (this report)
Pear Spring	1959, a period of post-earthquake activity (no data)
Pear Geyser	1878, described as a "spouting spring" 1961, frequently active, intervals 5 minutes, durations 2-3 minutes, heights to 12 feet 1974, one eruption to 6 feet observed by Bryan 1978, active (no data) 1990, washed areas and channel indicate significant activity during 1989-90 winter season 1990, single eruption seen by Stephens in August, height 6-10 feet
RSG-1	1947, active (no data) 1956, active when "East Round Spring" below overflow 1982-1989, cyclic but frequent with duration a few seconds, height 2-6 feet 5/25/1990, with Round Spring; one eruption to >7m witnessed, resulting in extended inactive period (this report)
RSG-2	1947, active (no data) 1956, active with RSG-1 1982-1989, cyclic with RSG-2, intervals minutes to 1+ hour, durations seconds, height 1-2 feet 5/25/1990, intervals of seconds, height to 2m (this report)

responsible for the extensive washed areas (which were untouched by major eruptions); the observed great eruption had a duration of 169 seconds and, especially near the end of the play, included numerous bursts higher than 15 meters, with some rocketing jets to probably near 20 meters. As with the major eruptions, this activity actually consisted of a series of shorter plays separated by brief but total pauses in the eruption (in this case, Round Spring was probably erupting for about 120 seconds of the 169 second duration).

Doubly Cyclic Nature of the Activity

The activity of Round Spring followed a doubly cyclic pattern. First, the eruptions occurred as a series of sequential eruptive episodes. Each episode lasted a few minutes. One would typically begin with a few splashes. Gradually, minor eruptions would become more common as the episode progressed, until it culminated with a major or (as observed once) a great eruption. A period of quiet then led into the next eruptive episode.

Eruptive episodes continued as an uninterrupted string until the end of that particular active phase. The active phases could end, evidently, at any point within an eruptive episode. The one complete active phase that was observed had a total duration of 6h58m. The next active phase had been underway for 3h01m when observations were discontinued because of darkness and extreme cold (≈ -10°C in high winds). The pause between the two active phases was 81m, during which there was total inactivity in a pool which stood below overflow.

The complete known record of the May 25 activity is shown in Table 2.

Subsequent Activity

By the morning of May 26, the activity of Round Spring had declined to a very low state. An early check showed that the water had cleared substantially from its murky appearance of the previous day. No eruptive action was seen in the course of about 30 minutes of observation, but a slight superheated boiling was still present. As a check, markers were placed at three points within the washed areas near the crater, and at two spots adjacent to the runoff channel.

Later that day, two small eruptions were seen. Both lasted but a few seconds and reached less than 2 meters high. They were not sufficient to wash any of the markers, but no additional, more sensitive markers were placed. On May 27, another check showed that the pool had dropped to a level fully 10 centimeters below overflow. The water was perfectly clear, totally calm, and felt little more than tepid; later that day the temperature was found to be only 131°F. All markers were still in place, as they still were on May 28 and 29. Following that date, the pool level varied from slight overflow to deep within the central vent and the temperature varied accordingly, but no further eruptions occurred. The markers placed on May 26 remained untouched on August 8.

It seems likely that the activity by Round Spring was a "one-shot deal," the effect of some impulse of energy into the Round Spring Group because of forces or causes unknown. That the entire group was involved was made clear by the activity of other springs in the area.

Associated Activity

Arnold Hague noted, around 1911, that: "These springs are of interest only for their connected relationships and fluctuating water supplies" [in Whittlesey, 1988]. Right there is an indication that even early on, it was recognized that these springs were of a changable nature, and that any change in one feature was matched by corresponding changes elsewhere within the group.

Indeed, the May 25, 1990 activity appeared to involve the entire Round Spring Group. If any features were unaffected by the May 1990 episode, then they were Pear Spring and Pear Geyser, interestingly the closest springs to Round Spring itself and historically the hottest and most active of the lot.

As one especially familiar with Yellowstone's geyser action, I noted immediately that RSG-1 and RSG-2 were extraordinarily active while Round Spring was animated. Both their frequency and force were substantially increased.

Per a study (unpublished) I produced in 1982, shortly after these geysers entered their current activity, RSG-1 and RSG-2 showed a clear relationship to one another. Most active was the larger RSG-1, whose eruptions lasted just a few seconds, but recurred on intervals of only a few seconds and reached up to 2m high. After a long series of such eruptions, accompanied only rarely by brief and very weak play by RSG-2, RSG-1 would cease erupting for as long as an hour. The renewal of eruptions was always triggered by an eruption of RSG-2, which would then quickly decline back to its more normal infrequency. Although no further studies about this activity had been performed since 1982, casual observations through the succeeding years indicated no significant changes.

But here, with Round Spring erupting, both RSG-1 and RSG-2 were extremely active and powerful. At times, RSG-1 was nearly perpetual; intervals for RSG-2 were seldom more than 10 seconds long. Both geysers also played higher than normal, some of the play by RSG-1 certainly reaching well over 3 meters high. Most remarkable was a single eruption by RSG-1, near the end of an inter-episode recovery period. This easily reached 7 meters high with true cone-type jetting for a duration of more than 20 seconds.The relationship between RSG-1 and Round Spring then became obvious. Round Spring did not erupt again until the end of its longest recovery interval of the episode, and the succeeding active phase was the only one observed to consist of only a single major eruption preceeded by no splashes or minor eruptions. This was completely out of character. Also, following this eruption by RSG-1 was a hiatus of more than 6 minutes during which neither it nor RSG-2 played.

Yet another way this relationship appeared occurred when Round Spring ended its active phase at 16:33. Both RSG-1 and RSG-2 simultaneously ceased playing; they did not re-start until 17 minutes later.

Meanwhile, other members of the group were also active. West Round Spring probably had at least two eruptions. One was suspected by Heinrich Koenig on the basis of a billowing steam cloud at about 11:00 on May 25; the second was directly seen by myself at 15:14. Both eruptions apparently were single bursts about 2 meters high, but they are the only eruptions from the pool observed since 1971. Following the latter eruption, West Round Spring dropped to a level fully 50 centimeters below overflow.

Finally, near the end of Round Spring's active phase, at about 16:15, North Round Spring filled to a very high level. Strong convection and bubbling was visible from the paved trail, and was vigorous enough for some to have called the activity an eruption; such would be this spring's only eruption on record.

Conclusion

An event of unknown cause or source caused extraordinarily frequent and powerful eruptive activity among members of the Round Spring Group on May 25, 1990. No corresponding changes were evident in any of the neighboring hot spring groups, although it is interesting to note that Splendid Geyser, among the nearer features, had its first activity in two years just two days after Round Spring's activity. There was no earthquake about this time, though several major quakes did occur worldwide in the following days. This must simply be taken as an event of unknown origin and, typical of its sort, of very brief duration.

Whatever the reason, the Round Spring Group has now proven itself capable of major-scale geyser activity.

Acknowledgments

The discovery of Round Spring's major eruptions was a group effort, and the data gathering on May 25 was performed by several geyser gazers. Thanks to Heinrich Koenig, Lynn Stephens, and Mike Keller for recording and passing along eruption times while I was away gathering camera equipment, supplies and warmth. Contributions were also made by Ann Deutch, Tom Hougham, and Ralph and Donna Friz.

TABLE 2

Observed Eruptive Activity, Round Spring, May 25, 1990

	Intervals (minutes)			Durations (seconds)				
Time	M to M	m to m	Recov	Splash	Minor	Major	Great	Height(m)
0935						unkn		
0959	24					unkn		
1020	21					unkn		7
1043		—			—			
1052		8			6			2
1056	36	4				56		8
1111			15		—			
1115		4			7			
1121		6			11			1
1124		3			8			2
1128	32	4				48		10
1138			10	splash				
1141		3		splash				
1144		3			13			2
1145		1		splash				
1149	21	4				55		7
1159			10	splash				1
1202		3		splash				1
1206		4		splash				2
1209		3			18			4
1214		5			14			3
1217		3			22			4
1222	33	5				34		8
1228			6	splash				1
1232		4			7			2
1233		1		splash				
1237	15	4				51		10
1256	19		19			37		6

1306			10	splash				
1307		1			5			2
1308		2			7			5
1313		5		splash				1
1316	20	3				32		8

brief gap in observations

1329	13					67		10
1342			13		7			
1346	17	4				45		10
1404			18		9			3
1410	24	6				29		8
1423			13					
1425	15	2				46		12
1442			17	splash				
1443		1			9			2
1446		3		splash				
1447		1		splash				
1451		5			5			1
1452		1		splash				
1455		3		splash				
1456		1			8			3
1501	36	5				36		10
1510			9		5			2
1515	14	5					169	15-20
1527			12		7			2
1530		3		splash				

temporary end of observations

1601					12		2
1606		5			6		1
1610		4			4		
1612	?	2				36	7
1624			12		9		2
1627		3		splash			
1628		1			10		3
1629		1		splash			3
1633		4		splash			

End Active Phase

Restart new active phase; hiatus = 81 minutes

1754						>20	>10
1807	13?						>10

Temporary End of Observations

1931					7		
1936		5			7		3
1940		4		splash			
1941		1			9		3
1944		3				31	8
1952	8		8			34	10
2000			8		10		
2001		1		splash			

Gap in Observations

2055	unkn— last observed major eruption	55	10+

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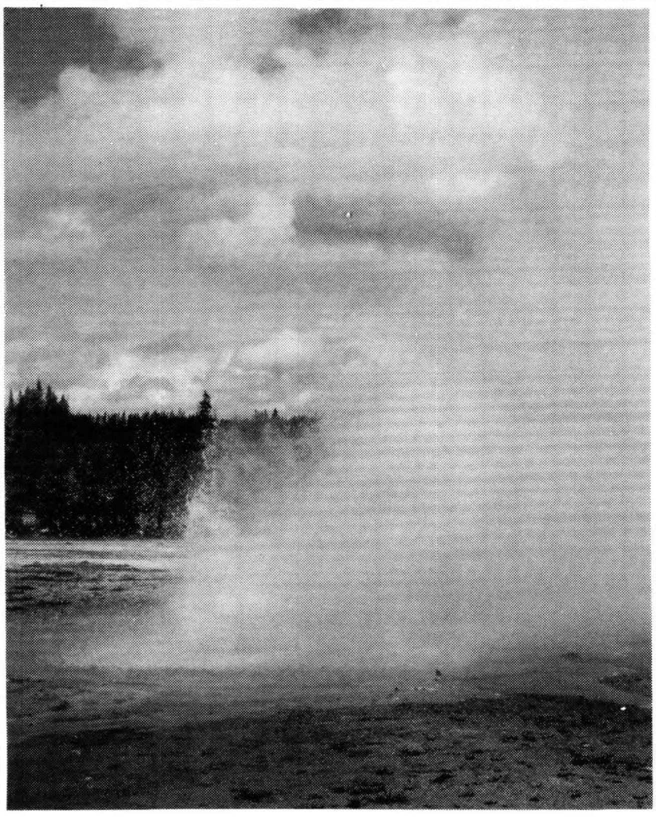

Another view of the May 25, 1990 activity of Round Spring. Photo by T. Scott Bryan.

Notes on Fluctuations in the Runoff from Spiteful Geyser
Upper Geyser Basin, Yellowstone National Park

by Tania Vincent and David Scheel

Abstract
This article expresses the speculation that a careful monitoring of the volume of Spiteful Geyser's runoff into Fan Geyser might provide a clue to the timing of Fan and Mortar's major eruptions.

It is well known that a portion of the runoff of Spiteful Geyser flows into the "East Vent" of Fan Geyser [Strasser, 1989; also referred to as the "North" or "Grand Canyon Vent" by Day, 1989]. The runoff into Fan is reported to be continuous except when Spiteful's water level is lowered following its own or (rarely) Fan and Mortar's major eruptions.

During the mid- to late-1970s, eruptions of Fan and Mortar Geysers were frequently preceeded by eruptions of Spiteful, and appeared to occur only after the runoff from Spiteful into Fan had been interrupted [Strasser, 1989]. Thus, Spiteful's runoff apparently delayed the eruptions of Fan and Mortar, probably via the cooling effect of the constant flow of water into Fan's plumbing. However, as the runoff has rarely been interrupted during the last ten years [Strasser, 1989], this information has not been useful in explaining or anticipating the onset of a major eruption of Fan and Mortar. While the belief that an eruption of Fan and Mortar may be precipitated when Spiteful's runoff stops is still prevalent among geyser gazers in the basin, the authors are unaware of any previous mention of frequent fluctuations in the *volume* of Spiteful's runoff or of the possible effect this may have on imminent eruptions of Fan and Mortar.

While waiting in hopes of seeing a major eruption of Fan and Mortar on 22-23 August 1990, we watched the pool of Spiteful. The water level fluctuated irregularly by 1 to 3 cm over a period of 5 to 11 minutes throughout the time we watched it. We did not attempt to correlate these fluctuations with any of the variable activity of Fan and Mortar's hot periods. However, we did note that when Spiteful's pool was high, the volume of runoff flowing into Fan's east vent was great; when Spiteful's water level dropped a few centimeters, the portion flowing into Fan was reduced to a very slight trickle (runoff into the river was still considerable, however).

Our time in the park was limited, and we had to stop our monitoring of Spiteful's runoff shortly after making this observation and before seeing Fan and Mortar erupt. However, the variation in the volume of runoff flowing into Fan may affect the timing of Fan and Mortar eruptions, or might prove to be a useful indicator to observers who wish to anticipate Fan and Mortar's major activity.

References

Day, J, 1989, Fan and Mortar Geysers in 1988, Upper Geyser Basin, Yellowstone National Park, Wyoming: Geyser Observation and Study Association, *Transactions*, Volume I, New Haven, Connecticut.

Strasser, P., 1989, Fan and Mortar Geysers, Upper Geyser Basin, Yellowstone National Park, Wyoming: Geyser Observation and Study Association, *Transactions*, Volume I.

Spiteful Geyser, as it appeared in 1974.
Photo by T. Scott Bryan

JEWEL GEYSER UPDATE - 1990

By: Ralph C. Taylor Jr.
and Brenda K. Taylor

1 ABSTRACT

This report describes the authors' observations of Jewel Geyser in August, 1990 and May, 1991. Ninety five closed intervals over a total of twelve hours in 1990 and one hour in May, 1991 are included in the data. A mathematical model relating the observed number of bursts in an eruption to the subsequent interval described in a previous paper is updated with 1990 observations. The interval to the next eruption is predicted within 2 minutes by adding 4m25s plus 1m5s for each observed burst in an eruption.

2 INTRODUCTION

This paper is an update to the authors' 1989 paper describing the eruption patterns of Jewel Geyser observed in August 1989 [Taylor 89]. The present paper includes data from twelve hours of observations on three days in August 1990 and one hour in May 1991. Our data include 85 closed intervals in 1990 and 10 closed intervals in 1991.

Section 3 of this paper describes Jewel Geyser and changes in its observed behavior between 1989 and 1990-91. Section 4 describes our observations. Section 5 is an analysis of the data. The mathematical model relating the number of bursts in an eruption to the subsequent interval, derived in our 1989 paper, is applied to the 1990 data. Section 6 presents our conclusions and outlines some questions that remain. Finally, Section 7 records the actual eruption times, burst counts, durations, and intervals.

3 Description of Jewel Geyser

Jewel Geyser is situated at the crest of the rise of the boardwalk from the Biscuit Basin parking lot, past Sapphire Pool and the junction of the boardwalk loop. The geyser formation is described in the author's 1989 paper [Taylor 89.]

Eruptions of Jewel observed in 1990 and 1991 did not differ significantly in form from those observed in 1989. As an eruption neared, the water gradually rose over the formation until the sinter nodules in the formation near the vent were nearly submerged. The water then welled up rapidly with a surging action. Shortly before the eruption began a distinct "plopping" sound was often audible from the boardwalk, apparently resulting from wave action on the sinter on the northwest side of the crater. When the eruption was imminent, the water surged and domed over the vent, with some bubbling, for twenty seconds to one minute before the start of the eruption.

The eruption began with a sudden jet of water bursting upwards at an angle to the southwest. The eruptions consisted of from one to eight short, sudden bursts. No 8-burst eruptions were observed in 1990 or 1991.

The bursts each lasted only a few seconds, ranging from an estimated one and a half to ten meters in height. The bursts always ended abruptly. The 1990 and 1991 pattern was similar to the pattern that we observed in 1989 and that reported in 1988 [Landis 88].

We categorized the bursts into four types. Small bursts reached 1.5 to 3 meters in height. The splashes from these bursts fell back into the pool of water around the vent. Medium bursts reached 3 to 4 meters in height.

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These medium bursts splashed on the sinter around the vent but did not cross the prominent sinter mound to the southwest of the vent. Large bursts reached over 5 meters in height and splashed out of the inner formation, across the sinter mound, and to the gravel wash area beyond the edge of the sinter platform. The large bursts collapsed so suddenly that the water, having been discharged at a 20 degree angle to the vertical, fell to the ground in a delayed splash that ended well after the water over the vent had subsided. A few bursts were huge, some reaching fully halfway to the boardwalk.

Each eruption consists of one or more distinct bursts, each lasting from three to eleven seconds, separated by five to fifteen seconds. The water in the crater remains high between bursts, welling up distinctly before each burst.

4 Observed Eruption Data

The tables of observed data are included as Section 7 of this paper. For all 1990 and 1991 observations after 4 Aug 90 we recorded the burst count and the total duration of the eruption from the start of the first burst to the end of the last burst.

Figure 1 shows the distribution of the observed bursts by burst size. Each vertical bar represents the percentage of the eruptions for one day that are small, medium, large, and huge. The burst size distribution is similar for the days for which we have data. The difference in the burst distribution for the first day (10 Aug 89) may be as much an artifact of our evolving technique of classification of bursts by size as any real variation in the bursts themselves. Overall, 30% to 40% of the bursts were small, slightly more (34% to 42%) were medium,

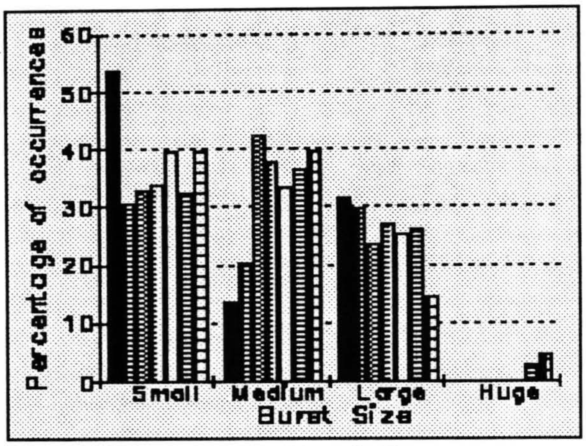

Figure 1 - Jewel Geyser Burst Size Distribution

and 25% to 30% were large. Only a few bursts were classed as huge.

Figure 2 shows the distribution of the eruption intervals observed in 1990 compared to the distribution of intervals observed in 1989. The distributions are similar in shape. The 1990 data show a minor peak at 4m and a broad, higher peak between 7m and 9m. The intervals observed in 1990 ranged from 3m48s to 14m31s, compared to a 1989 range of 3m46s to 13m45s. These data show a slightly wider variation than reported earlier in

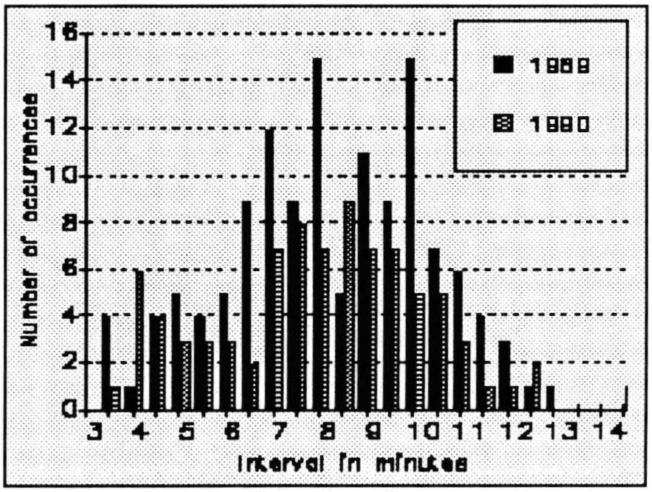

Figure 2 - Jewel Geyser Interval Distribution

JEWEL GEYSER UPDATE - 1990-91

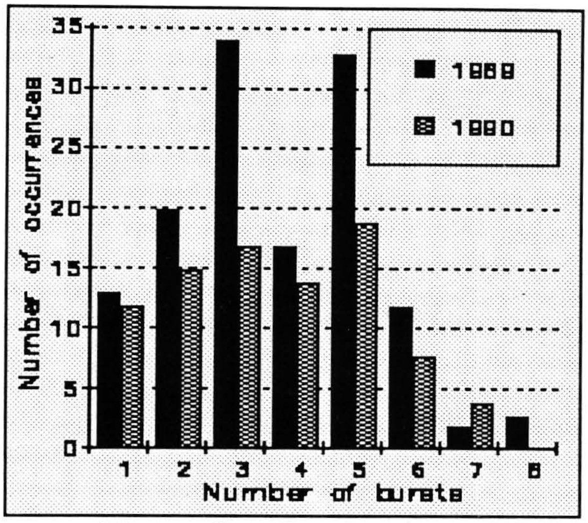

Figure 3 - Jewel Geyser Bursts Per Eruption

[Bryan 1986] and [Marler 73], but are consistent with more recent observations reported in [Landis 88]. We see no significant difference in the 1989 and 1990 distributions.

Figure 3 shows the distribution of the number of bursts per eruption in 1989 and in 1990. Some eruptions we saw in 1989 had as many as eight bursts; these eruptions generally had 7 or 8 small bursts and one or two large or medium bursts. In 1990 we saw several eruptions with seven bursts; they had a mix of large, medium, and small bursts. The 1989 burst distribution is bimodal with peaks at three and five bursts and a notch at 4 bursts. The mean for all eruptions in 1989 was 5.65 bursts. The 1990 eruption data is more even, with almost equal numbers of eruptions with 1, 2, 3, 4, and 5 bursts. Eruptions with six bursts were only half as numerous, and those with seven bursts about a fourth as common. The average number of bursts in the 88 eruptions that we observed in 1990 was 3.54, significantly fewer than the 1989 average of 5.65 bursts. Marler reports that most eruptions of Jewel Geyser consisted of 2-3 bursts [Marler 73]. Bryan reports a range of 1-6 bursts, with two or three being most common [Bryan 86].

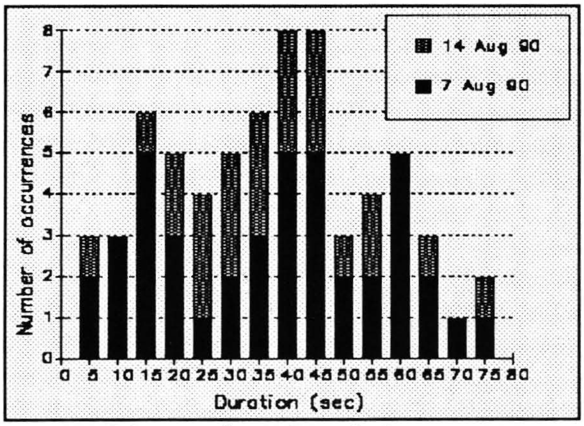

Figure 4 - Jewel Geyser Duration distribution

Figure 4 shows the distribution of eruption durations. The data for 7 Aug 90 and 14 Aug 90 differ in distribution, with more short eruptions in the 14 Aug 90 data.

We expected the duration distribution to follow the burst count distribution closely, since the eruption consists of three to five second bursts separated by five to ten second pauses. The difference in eruption duration distribution between 7 Aug 90 and 14 Aug 90 is echoed to an extent in the burst count for the same days, shown in Figure 5. The eruptions of 7 Aug 90 generally had fewer bursts and appear to have had shorter durations. There were more durations in the 20 to 50 second range on 14 Aug 90 than any other duration. This correlates with the large number of 3, 4, and 5 burst eruptions on that day. The general shape of the distributions for 7 Aug 90 is also similar.

The overall duration distribution pattern generally follows the number of bursts distribution, as expected. The eruption duration distribution extends from and 5 to 60 seconds, with 15 to 45 second eruptions most common.

5 Analysis of Eruption Patterns

Our 1989 paper described a linear relationship between the number of bursts in an eruption of Jewel Geyser and the subsequent interval. In this section we analyze our 1990 and 1991 data to determine what changes, if any, have occurred between 1989 and 1990. Figure 6 is a plot of our 1989, 1990, and 1991 eruption intervals as a function of the preceding eruption burst count. The graph shows that the trend to increasing intervals following eruptions consisting of more bursts continues in our 1990 and 1991 data.

Figure 6 includes the 130 observed closed intervals from 1989, 86 closed intervals from 1990, and nine closed intervals from 1991 as a function of the number of bursts in the preceding eruption. The lines represent least squares curve fit for each year's data.

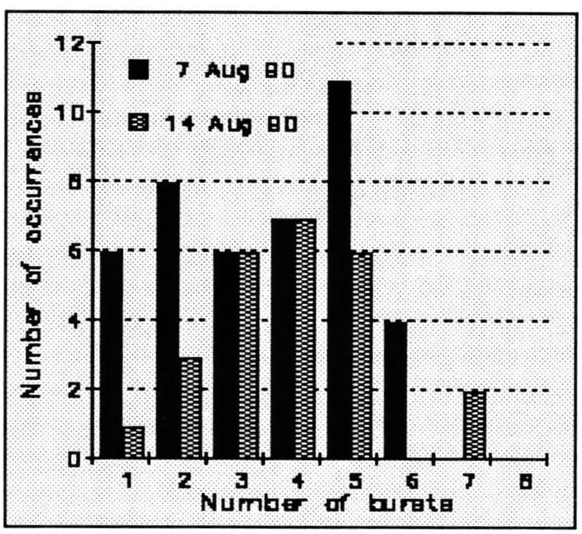

Figure 5 - Jewel Geyser Burst distribution

The trend of the data for 1990 and 1991 closely follows the trend of the 1989 data. The points for three burst eruptions in 1990 and 1991 are less scattered than those in 1989. In general, there are fewer extreme points in the 1990 and 1991 data.

The 1990 trend line (the long dashed line) is very similar to the 1989 trend line (the solid line). The slope of the 1990 line is slightly higher than that of the 1989 line, indicating a larger increase in expected interval for each additional burst, but the lines are nearly coincident. The 1991 trend line (dotted) has a markedly less steep slope, but is based on only nine data points. Considering the small 1991 data set, we can conclude that there is no significant change in behavior of Jewel Geyser over the period of study.

The values of A_0 (the Y intercept, or constant expected interval following a hypothetical zero burst eruption) and A_1 (the slope, or the increase in expected interval for each additional burst) are shown in Table 1 for the days for which data was taken and for the complete annual data sets. The table also includes some statistical measures of the curve fit chosen.

Although the intercept values (A_0) vary from 3.4 minutes to 5.29 minutes, the varying slopes result in predicted intervals that are quite close for the range of burst counts observed. Note that the curves all lie within a tenth of a minute at two and three bursts, and the 1989 and 1990 curves are within a few seconds of each other from 2 to 5 bursts (Figure 6).

The equations relating the eruption interval to the observed burst count of the preceding eruption for our 1989, 1990, and 1991 data are:

JEWEL GEYSER UPDATE - 1990-91

I = 4.64 + 1.02 × Bursts (1989)

I = 4.10 + 1.15 × Bursts (1990)

I = 5.04 + 0.79 × Bursts (1991)

These equations all yield similar predictions for intervals following eruptions with 2 and 3 bursts. The observed increase in interval following eruptions with more bursts was stronger in 1990 than in 1989, and significantly weaker in 1991. Of course, the 1991 trend is based on only nine observations over one hour. The mean interval for the 1989 and 1990 data sets are similar, 8m26s in 1989 and 8m13s in 1990.

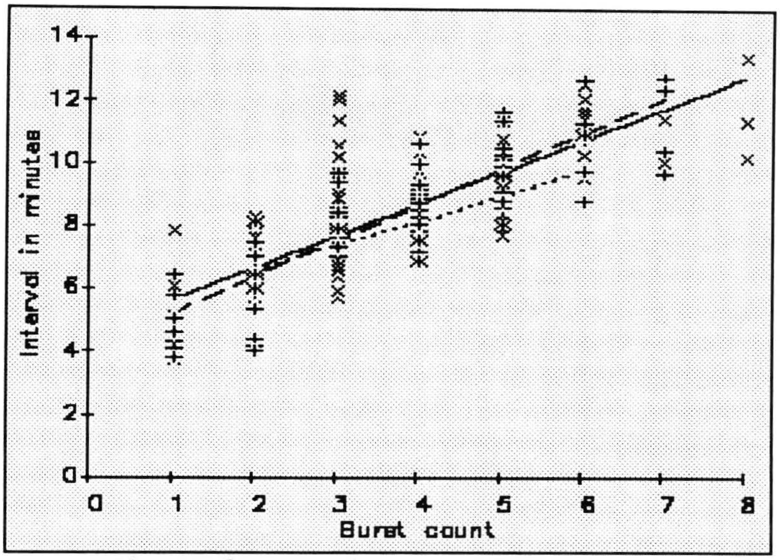

Figure 6 - Jewel Geyser Burst Count vs Subsequent Interval

We also analyzed the day to day variations in the eruption patterns to see whether any short term variations were present. Figure 7 shows the daily straight line least squares linear fit for our 1989 data, and Figure 8 shows our 1990 data (solid lines) and 1991 data (dashed line).

In Figure 7, the dashed line represents the data for 16 Aug 89. On this one day the eruption intervals averaged a full minute longer over the whole range of burst counts than on any other day in either 1989 or 1990. We have no explanation for this shift, and it was not observed in 1990 or on the single day of observation in 1991. We did not notice any obvious change in other activity in Biscuit Basin on 16 Aug 89. Figure 7 and Figure 8 together show a high degree of consistency from day to day and year to year in the burst-interval relationship.

6 Conclusions and Open Questions

The analysis in the preceding section shows that Jewel Geyser has maintained the same linear relationship between the number of bursts in an eruption and the subsequent interval in 1990 and 1991 that we observed in 1989.

For the periods of our observation, the interval following an eruption could be predicted by the following equations:

Date	A_0	A_1	Std Err of Prediction	Adjusted R Square	Correl. Coeff.
5 Aug 89:	5.008698	0.893417	1.077728	0.685137	0.835304
10 Aug 89:	3.941518	1.133577	1.216161	0.774857	0.884983
14 Aug 89:	4.136394	1.047837	0.947245	0.719092	0.851666
16 Aug 89:	5.290759	1.105943	1.627680	0.508674	0.724994
All 1989:	4.639957	1.021370	1.308346	0.628968	0.794887
4 Aug 90:	4.350937	1.151426	1.078324	0.837799	0.919965
7 Aug 90:	4.236633	1.145198	1.322986	0.662650	0.819196
14 Aug 90:	3.400726	1.218615	1.062551	0.735296	0.864179
All 1990:	4.100473	1.148458	1.206062	0.724394	0.853038
26 May 91:	5.036914	0.792963	1.039972	0.541938	0.774077

Table 1 - Jewel Geyser Burst Count vs Subsequent Interval Curve Fit parameters

JEWEL GEYSER UPDATE - 1990-91

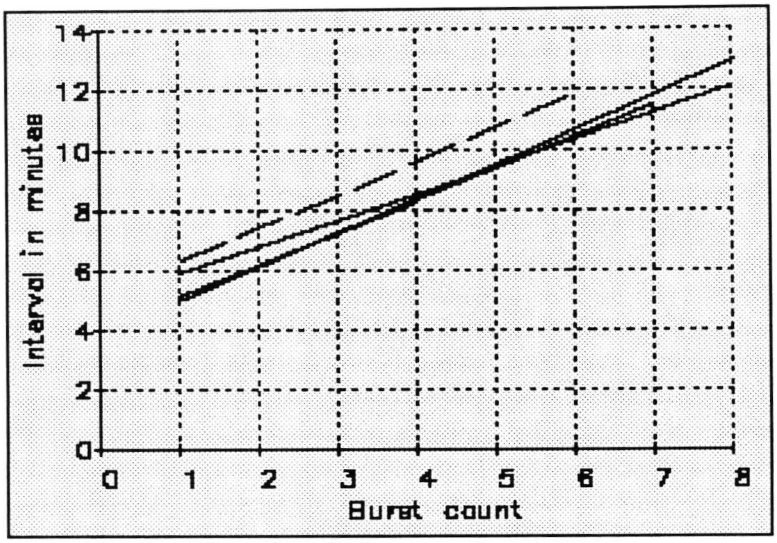

Figure 7 - Jewel Geyser Burst Count vs Subsequent Interval - 1989 Observations

During our 1990 and 1991 observations we used the simplified prediction for the next interval as reported in our 1989 paper (4m40s plus 1m for each burst). This estimate proved a useful tool even though a retrospective examination of the 1990 and 1991 data show that the eruption pattern had shifted slightly.

While watching the geyser, we found it useful to predict the next interval based on the number of bursts in the eruption, and then, at the predicted time, to listen for the "plop" of the waves against the sinter mound to warn of the onset of the eruption.

I = 4.64 + 1.02 × Bursts (1989)

I = 4.10 + 1.15 × Bursts (1990)

I = 5.04 + 0.79 × Bursts (1991)

When using the above equations to predict an eruption, one should allow a two minute leeway to be sure to see the eruption.

Based on our 1989 and 1990 data (ignoring the few 19991 data points), a composite curve fit leads to a modified predictor:

I = 4.42 + 1.07 × Bursts

or 4m25s plus 1m5s for each burst.

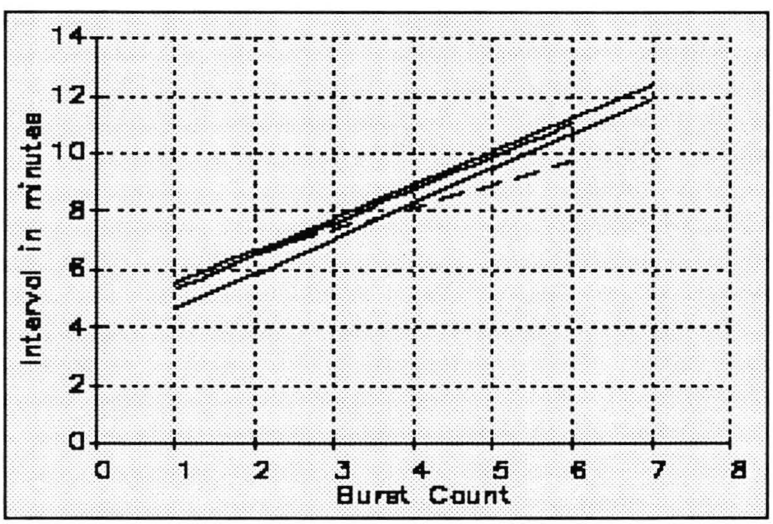

Figure 8 - Jewel Geyser Burst Count vs Subsequent Interval - 1990 and 1991 Data

7 Observed Data

The following pages show our observed data along with computed durations and intervals. Bursts are shown as large (L), medium (M), or small (S). The notation "no drain" means that the water level did not drop significantly following the last burst of the eruption. "Deep drain" means that the water drained out of sight from the boardwalk. Normally, the pool ebbed noticeably but water remained visible in the formation immediately after an eruption.

JEWEL GEYSER UPDATE - 1990-91

Saturday, 5/Aug/89

Time	Bursts	Interval
12:04:14	S	
12:12:04	SS	7:50
12:19:09	SSSSSLL	7:05
12:30:30	SSSL	11:21
12:40:35	SSLL	10:05
12:50:20	L	9:45
12:55:30	SLLL	5:10
13:04:20	SSSSLL	8:50
13:15:46	SSL	11:26
13:23:06	SSL	7:20
13:30:45	SSSLL	7:39
13:39:49	SSLLL	9:04
13:48:50	SSSL	9:01

-- Small/Large split uncertain--

Time	Bursts	Interval
13:55:57	SLLLL	7:07
14:07:13	SLL	11:16
14:15:19	L	8:06
14:19:49	SLSL	4:30
14:27:47	SLSLSS	7:58
14:38:32	SL	10:45
14:43:50	SLL	5:18
14:50:54	SSSS	7:04
14:59:02	SL	8:08
15:05:15	SSSLL	6:13
15:14:17	SL	9:02
15:22:36	SSSLL	8:19
15:32:58	SSSLL	10:22
15:41:16	SSSSS	8:18

Thursday, 10/Aug/89

Time	Bursts	Interval
11:29:57	LSLL	
11:40:02	SSSSSL	10:05
11:50:15	L	10:13
11:55:24	SLSSSL	5:09
12:06:17	SSSLSSSS	10:53
12:19:42	SLSSSL	13:25
12:32:13	SLL	12:31
12:40:36	SSSSSSSS	8:23
12:50:49	LSSSL	10:13
13:00:28	LLM	9:39
13:08:25	SL	7:57
13:14:23	SL	5:58
13:18:58	SSSML	4:35
13:27:00	SL	8:02
13:34:37	SMM	7:37
13:42:58	LM	8:21
13:48:55	LSMLSM	5:57
14:00:40	SMLSSL	11:45
14:12:14	SSLL	11:34
14:22:00	SMMSL	9:46
14:31:15	LML	9:15
14:37:39	L	6:24
14:41:25	SSSSS	3:46
14:49:09	LLMSS	7:44
15:00:00	SSLSMS	10:51
15:11:46	LMSSS	11:46
15:20:39	M	8:53
15:25:06	SLSL	4:27
15:34:27	LSMML	9:21

JEWEL GEYSER UPDATE - 1990-91

Monday, 14/Aug/89

Time	Bursts	Interval	
11:00:57	MMML		
11:08:35	LM	7:38	
11:15:51	M	7:16	
11:19:42	SSMS	3:51	
11:26:46	SSM	7:04	
11:32:31	MMM	5:45	
11:38:26	SMMML	5:55	
11:47:52	LSS	9:26	
11:56:15	SMLL	8:23	
12:03:47	SMMM	7:32	
12:12:02	SMSSML	8:15	
12:21:34	SL	9:32	
12:26:56	LMSML	5:22	
12:35:58	MML	9:02	
12:42:58	MLLLM	7:00	
12:53:28	MML	10:30	
13:01:43	MMLMM	8:15	
13:10:12	MSM	8:29	
13:16:44	MSL	6:32	No drain
13:23:34	MSSL	6:50	High water
13:30:48	SL	7:14	Normal drain
13:36:56	SMLLL	6:08	
13:47:07	SMMMS	10:11	
13:56:38	LMLLL	9:31	
14:07:02	ML	10:24	
14:12:27	MSM	5:25	
14:20:56	MLLLMSS	8:29	
14:31:00	SM	10:04	
14:37:48	SM	6:48	
14:45:12	SLLMSM	7:24	
14:55:29	SMMLL	10:17	
15:04:50	SSL	9:21	
15:11:35	LL	6:45	
15:18:24	SM	6:49	
15:24:46	SSSSS	6:22	
15:34:37	SSLMS	9:51	
15:43:51	L	9:14	
15:47:45	SSMSM	3:54	No drain
15:58:30	MLM	10:45	Deep drain
16:05:25	L	6:55	No drain
16:11:30	SMMMS	6:05	
16:21:59	LLLML	10:29	Deep drain
16:32:21	SLM	10:22	
16:40:43	LSM	8:22	
16:50:17	SLL	9:34	
16:57:20	SMSL	7:03	
17:05:10	ML	7:50	

Wednesday, 16/Aug/89

Time	Bursts	Interval
10:47:25	M	
10:53:12	MLLSM	5:47
11:01:53	SMM	8:41
11:14:02	SMMMM	12:09
11:25:32	MSSSML	11:30
11:36:45	LMMMSS	11:13
11:48:50	MMSMS	12:05
11:58:45	MML	9:55
12:07:45	SLM	9:00
12:18:19	SL	10:34
12:25:10	MMLM	6:51
12:35:30	LSS	10:20
12:43:55	L	8:25
12:48:33	SML	4:38
12:59:53	SSMSSM	11:20
13:10:45	MMLLM	10:52
13:20:45	L	10:00
13:25:18	MMLM	4:33
13:34:39	SMMSS	9:21
13:43:05	LMM	8:26
13:53:20	L	10:15
13:57:12	MSL	3:52
14:05:50	SLM	8:38
14:14:42	SML	8:52
14:21:20	SL	6:38
14:28:34	SMSML	7:14
14:39:54	LM	11:20
14:47:08	SSL	7:14
14:57:18	MSM	10:10
15:06:57	MMM	9:39
15:18:57	MSL	12:00

JEWEL GEYSER UPDATE - 1990-91

Saturday, 4/Aug/90

Start	Stop	Bursts	Duration	Interval	Notes
12:31:10		LL			(Maybe more bursts)
12:39:06		SM		7:56	
12:46:05		M		6:59	
12:50:59		SMLMM		4:54	
13:00:55		MMSL		9:56	
13:11:28		LMMSL		10:33	
13:21:35		L		10:07	
13:27:18		MMSSSMM		5:43	
13:36:58		L		9:40	
13:41:56		LSMMLL		4:58	Deep drain (7 cm)
13:54:39		LL		12:43	
14:00:50		S		6:11	
14:05:32		SMML		4:42	
14:13:50		SSSSSSL		8:18	deep drain (7 cm)
14:26:36		MMLSSM		12:46	deep drain (10 cm)
14:37:46		MSS		11:10	
14:47:27		SMMMSL		9:41	deep drain (7 cm)
14:58:43		MMLM		11:16	
15:07:54		L		9:11	
15:12:17		SSL		4:23	
15:19:56		SM		7:39	

JEWEL GEYSER UPDATE - 1990-91

Tuesday, 7/Aug/90

Start	Stop	Bursts	Duration	Interval	Notes
09:29:17	09:29:20	M	0:03		
09:35:42	09:36:37	SLSSL	0:55	6:25	
09:44:20	09:44:37	LL	0:17	8:38	
09:50:45	09:51:43	LLSMLM	0:58	6:25	
09:59:32	09:59:37	M	0:05	8:47	
10:03:52	10:04:00	L	0:08	4:20	
10:09:40	10:10:54	MMMLS	1:14	5:48	
10:20:03	10:21:03	MLLSS	1:00	10:23	
10:28:38	10:28:44	L	0:06	8:35	
10:33:14	10:33:42	MLSM	0:28	4:36	
10:42:17	10:42:28	SM	0:11	9:03	
10:46:28	10:46:48	SL	0:20	4:11	
10:50:50	10:51:32	SSLM	0:42	4:22	
11:01:28	11:02:03	MLSML	0:35	10:38	
11:09:24	11:10:22	MMLL	0:58	7:56	
11:19:21	11:19:28	L	0:07	9:57	
11:23:28	11:23:59	MML	0:31	4:07	
11:33:10	11:34:08	MSLL	0:58	9:42	
11:43:46	11:44:10	ML	0:24	10:36	
11:51:48	11:52:28	SSM	0:40	8:02	
11:59:04	12:00:05	SSSMS	1:01	7:16	
12:08:10	12:08:46	SMM	0:36	9:06	
12:16:37	12:16:48	L	0:11	8:27	
12:21:42	12:21:57	ML	0:15	5:05	
12:27:32	12:28:08	SSSL	0:36	5:50	
12:35:24	12:36:02	SLL	0:38	7:52	
12:43:13	12:44:06	SSLLML	0:53	7:49	
12:52:58	12:53:09	SL	0:11	9:45	
12:59:36	13:00:39	SSSMS	1:03	6:38	
13:09:55	13:10:38	MSSM	0:43	10:19	
13:18:27	13:19:08	SMSSM	0:41	8:32	
13:28:03	13:28:46	SLSSS	0:43	9:36	
13:39:43	13:40:32	SSSMM	0:49	11:40	
13:48:32	13:48:48	SM	0:16	8:49	
13:56:01	13:56:38	SLM	0:37	7:29	
14:04:17	14:04:48	SSSM	0:31	8:16	
14:13:35	14:13:49	SL	0:14	9:18	
14:20:37	14:21:46	MMMMSS	1:09	7:02	
14:35:08	14:35:50	SSMSM	0:42	14:31	
14:45:26	14:45:55	MMM	0:29	10:18	
14:54:49	14:55:46	SSMMMS	0:57	9:23	
15:05:37	15:06:24	SMMLL	0:47	10:48	

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Start	Stop	Bursts	Duration	Interval	Notes
Tuesday, 14/Aug/90					
12:12:57		SL			
12:18:17	12:18:49	MMMM	0:32	5:20	
12:27:19	12:27:40	MML	0:21	9:02	
12:34:20	12:34:33	SSSML	0:13	7:01	
12:42:11	12:42:41	MSSS	0:30	7:51	
12:51:05	12:51:38	MMM	0:33	8:54	
12:58:19	12:59:33	LLSMLSS	1:14	7:14	
13:10:42	13:11:35	LMLLM	0:53	12:23	
13:19:32	13:20:24	SMSLM	0:52	8:50	
13:30:02	13:30:20	SM	0:18	10:30	
13:34:03	13:34:50	MLLHM	0:47	4:01	
13:45:26	13:46:00	SSLL	0:34	11:23	
13:54:44	13:55:26	LSM	0:42	9:18	
14:02:02	14:02:06	S	0:04	7:18	
14:05:50	14:06:26	SHSSM	0:36	3:48	
14:14:05	14:14:29	SSL	0:24	8:15	
14:22:41	14:23:11	SMML	0:30	8:36	
14:29:52	14:30:32	SMSM	0:40	7:11	
14:37:50	14:38:30	LMML	0:40	7:58	
14:46:33	14:47:36	LSSSLSM	1:03	8:43	
14:56:57	14:57:42	LMH	0:45	10:24	
15:04:50	15:05:17	MSML	0:27	7:53	
15:12:53	15:13:10	SL	0:17	8:03	
15:18:16	15:18:39	MMM	0:23	5:23	
15:26:42	15:27:24	SMLLM	0:42	8:26	
Sunday, 26/May/91					
11:35:11	11:35:48	SMML	0:37		
11:42:44	11:43:12	SSSM	0:28	7:33	
11:49:37	11:50:36	LMSMM	0:59	6:53	
11:57:42	11:58:02	LL	0:20	8:05	
12:03:42	12:03:58	SS	0:16	6:00	
12:10:10	12:11:03	SMMMS	0:53	6:28	
12:19:45	12:20:06	LH	0:21	9:35	water rise, bubbles, and surging at 12:25:00
12:27:53	12:28:52	SSMMMS	0:59	8:08	
12:38:49	12:39:14	LMH	0:25	10:56	½ way to boardwalk
12:46:42	12:47:52	MMSSSSM	1:10	7:53	

JEWEL GEYSER UPDATE - 1990-91

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Whistle Geyser
Black Sand Basin, Yellowstone National Park
Observations of July 18, 1991
by Clark Murray

Abstract

Eruptions by Yellowstone's Whistle Geyser have been very rare. The author witnessed an eruption from near its beginning and found the activity to be quite different from that of most previously published descriptions.

On the night of July 18, 1991, I had the rare opportunity to see an eruption of Whistle Geyser from near the beginning of the play. The steam cloud was first spotted from the main road at 21:00 (exactly). I quickly pulled into the parking lot at Black Sand Basin, expecting to see a steam phase of the sort described by Marler [1973]. Instead, I was surprised to find the geyser in a full water phase eruption. This eruption consisted of two to three meter bursts, looking a great deal like Little Cub Geyser. Most earlier reports stated that the water phase was very short, having water for only the very first moment. But in this case the water phase continued until 21:04. Far from being brief, it lasted four to five minutes, possibly longer. Rocco Paperiello [personal comm., 1991 and 1992] has located a reference by T.H. Lystrup [1931] which describes the eruption of August 2, 1931 as also having had a five minute water phase. However, most descriptions of Whistle note the shortness of the water phase.

A seasonal naturalist witnessed the 1968 eruption, and it was his impression that the water had a "cool" appearance to it, an impression that Marler discounted highly. After witnessing an eruption personally, I can see why the naturalist reported as he did. As the algae in the crater was broken down by the eruption, it gave the water a unique sea-green color which did, in fact, give the water a cold appearance.

At 21:04, the water and steam began to mix, spraying 20 to 25 meters high and, at first, chugging like a steam locomotive. After five minutes (at 21:09), this converted into a violent steam-only phase, roaring but not whistling, for about 40 minutes. By 21:50 there was a detectable decrease in the strength of the steam phase. From this point on the steam phase grew gradually weaker. More than one hour later (23:06), steam still welled from the crater but without the great pressure of before.

Whistle then required about 2 1/2 days to recover and refill its system.

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Whistle Geyser, July 18, 1991. Photo by Clark Murray.

Activity of the Fountain Geyser Complex

Yellowstone National Park, Wyoming

Gordon R. Bower

Abstract

The Fountain Geyser Complex, including a minimum of eleven geysers, is located near Fountain Paint Pots, fourteen kilometers north of the Upper Geyser Basin. This paper discusses some aspects of the activity of the complex during the summer of 1990.

Introduction

The Fountain Complex is situated on a large sinter platform on the north side of the hill on which Red Spouter and Fountain Paint Pots sit. The area around the complex is devoid of vegetation except for a few sprigs of grass. Most of the surface is covered by a few centimeters of loose sinter. Runoff channels are carved down to solid geyserite.

The following springs are included in the Fountain Complex:

1-Fountain Geyser, erupting from a large crater surrounded by a sinter platform to 10-25 meters about twice per day for 30-60 minutes;
2-Morning Geyser, erupting on rare occasion from the pool beyond Fountain to 40-60 meters, but usually a quiet pool without overflow;
3-Clepsydra Geyser, erupting almost continuously from a low yellowish cone to 3-10 meters;
4-Jet Geyser, erupting from an asymmetric cone on irregular intervals to 2-5 meters for 5-80 seconds;
5-Twig Geyser, erupting from a beaded crater to 2-5 meters on irregular intervals and durations;
6-Spasm Geyser, boiling on one side of its double crater and overflowing for many hours at a time about twice per day;
7-Jelly Geyser, erupting occasionally to 2-4 meters for the large crater and more weakly from a nearby satellite;
8-"Super Frying Pan" (more formally known as UNNG-FTN-2), erupting from a group of fissures to 1-3 meters every 80-180 minutes for 10-17 minutes;
9-"Bearclaw" Geyser, erupting to 30-100 centimeters every 10-55 minutes for 1-5 minutes;
10-Sub Geyser, erupting frequently below ground level, but occasionally reaching the surface; and
11-New Bellefontaine Geyser, erupting with great frequency to 1-3 meters for a few seconds at a time.

The Fountain Group includes numerous other geysers. Two of these were also observed: UNNG-FTN-3, erupting every 10-60 minutes when active, and Old Bellefontaine Geyser, often dormant and always irregular. Both are located below Jelly Geyser.

Ten of the thirteen geysers listed above are discussed in [Whittlesey 1988,] and all except "Bearclaw" Geyser are described in [Bryan 1986.]

Description of activity for each member of the complex

Fountain Geyser:

After an eruption, the water level dropped about one meter within half an hour. The level rebounded seventy to ninety centimeters over a period of about four hours. The remainder of the quiet phase was characterized by occasional palpitations, no more than a few centimeters high. These are easily observed by watching the small rocks at the back of the crater.

The eruption begins with a larger rise in water level, of ten to fifteen centimeters. This usually occurs after 10-12 hours, but may happen in only 5-7 hours or a longer interval of over sixteen hours.

The rise in water level took only a few seconds. Within a few more seconds, the water boiled over the vent at the front of the crater. This built in force to as much as two meters. The first burst followed the water rise by less than a minute. Most bursts were 3-6 meters high and threw little water beyond the sinter shoulders of the crater, but larger bursts as high as twenty meters occured in most eruptions. A few of these threw water, sometimes still hot, onto the boardwalk. Durations averaged fifty minutes.

Often, Fountain erupted on a regular pattern of 11-12 hour cycles. At these times, Fountain could be predicted as easily as Artemisia or Pink Cone Geysers, and the observer could have considerable confidence in assessing the situation upon arrival. On the other hand, the same portion of the cycle tended to be observed on several consecutive days.

Fountain directly influenced Morning, Clepsydra, Jet, Spasm, "Super Frying Pan," and "Bearclaw" Geysers; it is likely that the entire complex was affected.

Morning Geyser:

The water level in Morning's main vent rose and fell in sympathy with Fountain's. Morning could be seen more easily from the overlook than Fountain, making it a convenient way to watch pressure build in the system. When Fountain erupted, much of its water pours into Morning and was recycled.

During 1990, the only observed activity in morning was periodic weak convection over the main vent, usually during Fountain's longer intervals. However, it had frequent active cycles in 1991; a discussion of them is found in [Stephens 1991.]

Clepsydra Geyser:

The near-constant splashing of Clepsydra Geyser is often the only activity of any size in the Fountain Complex for hours at a time. Probably more people see this geyser than any other except Old Faithful. There were three things here that the observer should note.

The first was the relative strength of the eruption. It was at its weakest during and shortly after Fountain erupted, when it often reached only three meters. The peak strength was reached near mid-interval in the Fountain cycle, when strong jetting could exceed ten meters. Some idea could be had of the position in the cycle from this.

Another, more important, indicator for Fountain was the sound Clepsydra produced; before most eruptions, the splashing sound gradually became a Riverside-like chugging and roaring. In most cases this indicated Fountain was one to two hours away. On one occasion, however, the roaring suddenly ceased; it was over six hours until the next eruption of Fountain.

One of the most interesting aspects of Clepsydra's activity was the pause. Shortly after some of Fountain's eruptions, bursts become weak and widely spaced; even these ceased in a few moments. Standing water poured back down the vents, producing a unique sound. After two to five minutes, the discrete splashes resumed from the back vent. Shortly afterward the drowned front vent reactivated and normal activity resumed. No pattern is known for when this will occur, but it may indicate greater than usual energy release from the complex during the previous cycle.

A geyser of Clepsydra's size surely affected other members of the complex. These connections were not evident owing to the large portion of the time Clepsydra is active.

Jet Geyser:

Fountain and "Super Frying Pan" exercised almost total control over the activity of Jet Geyser. A typical active cycle proceeded as follows:

After an eruption of Fountain, Jet had no eruptive activity for several hours. A few minutes after "Super Frying Pan's" second or third eruption following Fountain, Jet would have a weak eruption. These continued at irregular intervals, often alternating between 7-12 and 20-30 minute intervals.

While Fountain was quiet, Jet almost never erupted during "Super Frying Pan." [Stephens 1991] divides Jet's eruptions into series based on this consistently longer interval. Immediately after each of "Super Frying Pan's" eruptions, it would have two eruptions as close together as 4m30s. With each successive "Super Frying Pan," Jet tended toward greater frequency and regularity. Even if eruptions were occuring frequently, discharge remained slight.

Many people believe that if Jet is erupting every 7-10 minutes, Fountain is due to erupt. The only basis found for this claim was a increase in regularity over time, not directly related to Fountain. Such activity generally would begin after 10-14 hours and continue until Fountain's next eruption. If Fountain's intervals were in that range, the illusion of a relationship might appear, but Fountain might have played after only a few scattered Jet eruptions or have waited for dozens. The fact that the regular activity continued longer (and was, therefore, more likely to be seen) during an extremely long Fountain interval suggested the opposite: Jet was more likely to be regular if Fountain was irregular and infrequent.

There were two clues to Fountain's activity provided by Jet, though. First, if Jet did not erupt during a half hour or more of observation, the system had not recovered from the previous Fountain yet. Second, some (not all) eruptions of Fountain were preceded by a chugging steam phase of long duration from Jet in lieu of the final eruption before Fountain started. This effect also preceded a few "Super Frying Pan" eruptions, usually early in the cycle.

Jet's activity was altered drastically by Fountain's eruption. One more normal interval occured after Fountain started. After that, intervals fell to 30-200 seconds and durations to 5-35 seconds. An eruption of "Super Frying Pan" caused only a slight slowdown rather than complete cessation of activity. One final eruption occured seconds after Fountain's eruption ended.

At any point in Fountain's interval, Jet sometimes would splash weakly or briefly roar. Presumably these were eruptions for which the water level was too low to reach the surface. No effort was made to record the roars. Some of the splashes were recorded and appear in the data tables as "preplay."

Twig Geyser:

This spring appeared to be a rather distant relative of Fountain. It was probably affected to some extent by Fountain's activity, but it showed a clear relationship only to "Bearclaw" Geyser.

During some periods of observation, it appeared that a given duration was dependent on the preceding interval. While it probably would have been possible to do so with enough observation, no reliable method of prediction was devised.

Intervals could be over five hours long. During these long intervals, periods of steaming and gurgling, followed by splashing at depth in the crater, occured every few minutes for up to two hours before the eruption actually began. The water level rose further with each successive series of splashes. An eruption was imminent when standing water remained visible for a few seconds after splashing ceased. This splashing cycle was noted only during very long intervals; those of three hours or less started abruptly.

The eruptions began with vigorous splashing to 1-2 meters and a sudden rise of the greenish water in the crater. In under ten minutes, overflow was reached and some bursts were as strong as five meters. During the eruption, periods of vigorous bursting and gentle boiling alternated every 30-60 seconds. The eruption ended when the boiling declined and the pool drained. Some eruptions, generally the longer ones, had a concluding steam phase. Beginning about a minute after the water disappeared, steam billowed from the vent for 1-4 minutes.

Twig has a small satellite vent (known very informally as "Twiglet.") This small hole could start sputtering at any point during Twig's eruption, but invariably ended within a few minutes of the conclusion of Twig's eruption. There was no discharge. Data for this vent is listed in the tables as "S.V."

Spasm Geyser:

The intervals and durations of Spasm Geyser were both many hours in length. The activity usually began near the midpoint of Fountain's interval and either stopped shortly before Fountain started or continued until Fountain's runoff quenched the eruption.

Only the right vent took part in the eruption. The left vent did not erupt; it may even have acted as a drain for part of its neighbor's runoff. Given the volume of the boiling, discharge down the channel was rather low.

Eruptions began without warning. Initially some water was thrown as much as two meters above the pool level. The water level rose to overflow in 5-10 minutes. The height of the eruption was reduced as the crater filled; the surging reached a maximum of fifty centimeters during most of the eruption. When the crater was empty, sediment washed in by Fountain's runoff was plainly visible. This is stirred up during the eruption, causing the water to be gray and opaque rather than the more typical clear greenish water of the Fountain complex.

Spasm usually proved to be a highly reliable indicator for Fountain. It was not infallible, though, as it could not be counted on to stop and drain prior to the start of Fountain.

As was the case with Clepsydra, it was very difficult to infer connections to geysers other than Fountain. Jelly Geyser seemed to be affected, but this may simply have been the result of Spasm's runoff pouring into Jelly's satellite vent.

Jelly Geyser:

No eruptive activity was observed during the study period. The water level in its crater did rise and fall in a pattern clearly related to the complex.

In the hour after Fountain's eruption ends, the water dropped about one meter with the large crater. It rose at a constant rate to overflow, which was usually reached shortly before Spasm started. When Spasm reached overflow, "cold" (70° C) water flooded the satellite vent and precluded any possibility for eruption. The water level remained at overflow until Spasm stopped; it then dropped 10-15 centimeters and remained level until Fountain erupted.

"Super Frying Pan" (UNNG-FTN-2)

This rapidly expanding network of fissures between Jet and Spasm was among the most important springs in the complex.

The first eruption after Fountain occured after an interval of 130-180 minutes. The eruption consisted of violent sputtering from numerous vents, the highest droplets reaching two meters. Discharge was greatest in the first minute of eruption. This first eruption had a duration of only 10-14 minutes. Successive eruptions showed a trend toward higher water levels, longer durations, and shorter intervals.

The water level during the eruption could easily be observed by watching a small pool about five meters closer to Spasm than the other vents. No water was seen here during the first eruption of the series; steam was seen during the second, and it filled partially during the third and fourth. Overflow began with the fifth eruption and increased in volume with each eruption thereafter. As a result of the very long Fountain intervals that have occured occasionally in recent years, enough water has been discharged to create a shallow but discernible runoff channel. The status of this pool during most eruptions appears in the data table. If a time is given, it refers to the start of overflow.

Eruptions of "Super Frying Pan" occured during every observed Fountain eruption at approximately the same time they would have otherwise. It seemed, therefore, that "Super Frying Pan" was a controlling influence upon Fountain, and, therefore, the entire complex. Fountain's only effect upon Super Frying Pan was a slight increase in discharge and duration beyond what might have been expected otherwise. No definite minimum interval had to be reached before Fountain could erupt, however.

As noted above, Jet is directly connected to "Super Frying Pan." Except during Fountain's eruptions, the two almost never erupt in concert, and Jet's activity increased following "Super Frying Pan's" eruptions.

The above conclusions are an interesting contrast to a statement in [Bryan 1986] that indicates Fountain and Jet control "Super Frying Pan."

"Bearclaw" Geyser:

[Whittlesey 1988] notes a 1962 report of two vents near the boardwalk filling prior to the eruptions of Twig Geyser. "Bearclaw" was not a precursor to Twig in 1990, but the two were clearly related. Eruptions from the west and north vents were first observed in 1988 [Bryan 1989;] interestingly, no known reference mentions the non-eruptive east vent.

This feature has also been known as "Twig's Satellite Vents." The author objects to this name for two reasons: First, as described in the section for Twig, that geyser already has a satellite vent. Second, "Bearclaw" is a separate geyser, connected to but not part of Twig; it is no more Twig's satellite than Percolator Geyser is West Triplet's satellite.

Intervals were divided into three distinct types: "Fountain," "Twig," and "Non-Twig." The first type occured only during and immediately after eruptions of Fountain and was 10-13 minutes long. "Twig" intervals were those while Fountain was off but Twig was in eruption. These were much longer, 48-54 minutes. "Non-Twig" intervals were those occuring when neither Twig nor Fountain was active. These, 24-32 minutes long, were the most common variety. As with Jet, Fountain has a slightly delayed effect; the first eruption during Fountain occurs after a normal 24-54 minute interval, and there is one final short eruption after Fountain ends. The distinction between "Twig" and "Non-Twig" intervals is blurred somewhat, as the start or end of Twig's eruption produced a group of intermediate intervals. Twig seemed to have no effect during Fountain.

Durations also varied somewhat. During Fountain, eruptions lasted 3.5-5 minutes and gradually declined to a more normal 1.5-3 minutes. In some cases, Twig caused a slight reduction in duration.

Eruptions were divided into two forms. The "normal" form, when Fountain was inactive, began with a gradual rise of water in the three vents. Slight sputtering sometimes occured as the east vent started to fill. The north and west vents began to bubble slightly, and the north vent overflowed into the east vent. The bubbling built up to an eruption, reaching 50-75 centimeters from the north vent and a lesser height from the west vent. The east vent served only as a drain. Bursts, recurring about eighty times per minute, were splashes of small volume. At about the same time, the west vent quit and the north vent drained, still splashing. The water slowly dropped out of sight in the east and west vents.

While Fountain was erupting, "Bearclaw's" eruption began with the west and north vents splashing. All three vents filled rapidly. The strength was slightly greater than when Fountain was not active. Otherwise, the two types were very similar. The first few eruptions after Fountain stopped were of an intermediate nature but were classed with the former. In either case, discharge was slight, seeping through the gravel around the west and north vents toward Fountain's crater.

Also noteworthy was the temperature pattern during the cycle. In the thirty seconds preceding the eruption, the temperature abruptly climbed from 55° C to boiling. While the eruption was in progress, the temperature fell 12° C; presumably, the steam bubbles had sufficient energy to reach the surface before collapsing entirely. The temperature fell another 15° C as the vents drained. A steam phase, almost imperceptible to the eye or ear, was indicated by a sharp spike as high as 80° C shortly after the eruption. The temperature was in the 50-60° C range for the remainder of the interval.

As no formal study of this geyser had previously been made, more detailed data was kept on its activity than any other. The times at which each of the vents filled, began and ceased erupting, and drained were recorded.

New Bellefontaine Geyser:

New Bellefontaine's eruptions occured with great frequency. Every minute or so, it splashed vigorously from its vent beyond Clepsydra Geyser. Recording individual eruptions was close to impossible, and no clear relationship to other geysers was observed. There is a widespread belief that it is a member of the complex, however, and no evidence is offered to contradict that conclusion.

Sub Geyser:

Sub Geyser lies between Morning and New Bellefontaine. Its eruptions are mostly below ground level. Here, as with New Bellefontaine, no data was recorded and no evidence is offered in favor or against the connection. It is described as definitely being a member of the complex in [Bryan 1986.]

Other Features:

The activity of UNNG-FTN-3 and Old Bellefontaine Geyser was also recorded and the data included in the tables. No evidence to support connections to this area was found, nor was any connection inferred between the Fountain Complex and the Kaleidoscope and Sprinkler groups. It also seems unlikely that UNNG-FTN-1 and Red Spouter are members of the complex. Many still believe the complex extends beyond its known boundaries, and the possibility is certainly there.

In Conclusion:

The Fountain Complex changes its activity from year to year, sometimes even from week to week. The conclusions drawn here were based upon observations scattered throughout the 1990 season and the assumption (not necessarily valid) change significantly during that time. The activity patterns were certainly changed by the 1991 activity of Morning Geyser, perhaps never to return to the 1990 pattern. Only with long-term study over the years will the complex be understood. It is hoped that this fascinating area, largely ignored by geyser gazers, will receive more attention in future seasons.

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Table I

Statistical Summary

Event	N	Min	Q-1	Median	Q-3	Max	Qt.Dv.	Mean	Std.Dev.	C.Var.
Fountain:										
Duration.....	3	49m58s	---	50m17s	---	51m00s	---	50m12s	51.2s	1.7%
"Super Frying Pan:"										
Duration:										
All........	18	10m35s	11m20s	11m55s	12m25s	17m10s	32.5s	12m16s	1m36s	14%
Ftn. off....	15	10m35s	11m13s	11m50s	12m13s	13m15s	30.0s	11m46s	45.8s	6.5%
Interval.....	13	79m10s	95m27s	97m45s	101m34s	113m20s	3m03s	98m52s	9m55s	10%
Jet:										
Duration:										
All........	172	5s	30s	55s	1m00s	1m10s	15s	47.2s	17.1s	36%
Ftn. on.....	57	5s	21s	26s	30s	50s	4.4s	25.2s	8.2s	33%
Ftn. off....	115	27s	55s	59s	1m02s	1m10s	3,5s	58.1s	6.8s	12%
Interval:										
All........	178	47s	2m31s	8m09s	10m02s	90m50s	3m45s	8m36s	8m38s	102%
Ftn. on....	64	47s	1m33s	1m46s	2m36s	5m11s	31.5s	2m05s	50.6s	41%
Ftn. off....	114	5m07s	8m16s	9m44s	12m51s	90m50s	2m18s	12m00s	8m59s	75%
"Bearclaw: (North vent)"										
Duration:										
All.........	50	1m07s	2m01s	2m32s	2m46s	6m07s	22.2s	2m41s	1m02s	38%
Ftn. on.....	7	3m13s	4m32s	4m50s	5m03s	6m07s	15.5s	4m47s	53.6s	19%
Ftn. off:										
Twig on...	19	1m07s	1m57s	2m28s	2m32s	3m20s	18.4s	2m16s	58.7s	43%
Twig off...	24	1m25s	2m02s	2m26s	2m43s	3m23s	20.5s	2m25s	31.9s	22%
Interval:										
All.........	45	10m53s	26m10s	30m40s	39m00s	55m08s	6m25s	31m24s	10m31s	34%
Ftn. on.....	5	10m53s	11m24s	11m25s	11m30s	11m44s	3.0s	11m24s	18.9s	2.8%
Ftn. off:										
Twig on...	17	24m01s	33m49s	39m19s	42m29s	48m58s	4m20s	38m02s	7m21s	19%
Twig off...	23	22m30s	26m16s	27m18s	32m36s	55m08s	3m10s	30m50s	7m32s	24%
Twig:										
Duration.....	9	50m	1h06m	1h10m	1h34m	2h17m	14.3m	1h24m	32.5m	39%
Interval.......	5	1h57m	2h10m	2h13m	2h49m	3h04m	19.7m	2h29m	31.4m	21%
Steam phase:										
Duration:....	5	1m25s	1m28s	1m35s	2m39s	7m00s	35.6s	2m53s	2m23s	83%
Satellite Vent:										
After Twig...	9	3m40s	9m	18m	22m	58m	6.2m	22m	19.4m	87%
UNNG-FTN-3:										
Duration.....	21	13s	19s	20s	21s	23s	1s	19.7s	2.3s	12%
Interval......	20	5m23s	18m10s	23m41s	32m19s	48m40s	7m04s	23m40s	11.4m	48%

Table II
Percentage of Time in Eruption

(Mean duration/mean interval, from Table I)

Fountain	7.0%
"Super Frying Pan"	12.4%
Jet:	
All	9.3%
Fountain on	20.2%
Fountain off	8.1%
"Bearclaw:"	
All	8.6%
Fountain on	41.9%
Fountain off:	
Twig on	6.0%
Twig off:	7.8%
Twig	56%
UNNG-FTN-3	1.4%
Clepsydra	99.7%

Raw Data: Old Bellefontaine Geyser

July 1, 1990

Time	Intvl	Ftn
1916.15	(10m)	N
1926.xx	(46m)	N
2012.xx	(24m)	N
2036.xx	---	N

July 27-30: inactive.
October 27-28: inactive.
All eruptions consisted of a single burst.

Raw Data: Fountain Geyser

May 27, 1990

Boil	Start	Stop	Duration
???	1447	1538	51m

July 1, 1990

Boil	Start	Stop	Duration
???	0900IE		???
2052.28	2052.58	2143.15	50m17s

July 28, 1990

Boil	Start	Stop	Duration
1513.30	1513.47	1603.05	49m18s

July 29, 1990

Boil	Start	Stop	Duration

(0645- approximate time)
No eruption between 1040 and 2100
(2300- approximate time)

July 30, 1990

Boil	Start	Stop	Duration
	(0445- approximate time)		
???	1019IE	1058	???

October 27, 1990

Boil	Start	Stop	Duration

(2000- approximate time)

October 28, 1990 (MDT)

Boil	Start	Stop	Duration
???	0740IE		???

(2000- approximate time)

Raw Data: "Super Frying Pan"

May 27, 1990

Start	Stop	Dur	Intvl	Ftn	Pool
1536.xx	1547.xx	11.30	---	On	yes

July 1, 1990

Start	Stop	Dur	Intvl	Ftn	Pool
1951.20	2003.20	12.00	97.10	Off	yes
2110.30	2127.40	17.10	---	On	yes

July 27, 1990

Start	Stop	Dur	Intvl	Ftn	Pool
2009IE	2013.15	---	---	Off	no

July 28, 1990

Start	Stop	Dur	Intvl	Ftn	Pool
1157.45	1208.20	10.35	101.40	Off	1200.xx
1339.25	1350.35	11.10	97.45	Off	39.40
1517.10	1532.40	15.30	---	On	NR

July 29, 1990

Start	Stop	Dur	Intvl	Ftn	Pool
1130.45	1142.45	12.00	108.45	Off	no
1319.30	1331.55	12.25	101.15	Off	partial
1500.45	1512.30	11.45	100.30	Off	03.xx
1641.15	1653.25	12.10	94.50	Off	42.40
1816.05	1828.30	12.25	97.20	Off	17.15
1953.25	2004.40	11.15	---	Off	54.45

July 30, 1990

Start	Stop	Dur	Intvl	Ftn	Pool
0905IE	0908.30	---	---	Off	NR

October 27, 1990

Start	Stop	Dur	Intvl	Ftn	Pool
1746IE	1753.30	---	---	Off	no

October 28, 1990 (MDT)

Start	Stop	Dur	Intvl	Ftn	Pool
1030.00	1043.15	13.15	114.50	Off	no
1224.50	1236.30	12.40	113.20	Off	NR
1416.10	1428.00	11.50	97.35	Off	partial
1553.45	1605.10	11.25	90.15	Off	slt oflow
1724.00	1734.35	10.35	88.05	Off	slt oflow
1852.05	1903.10	11.05	---	Off	yes

Raw Data: Twig Geyser

July 1, 1990

Twig pply	Twig on	S.V. on	Twig off	S.V. off	Twg dur	S.V.dur	Steam	Stm dur	Interval
---	---	1841IE	---	1846.xx	---	---	---	---	---
---	1924.50	1937.45	2035.xx	2039.xx	(1h10m)	(1h01m)	no	---	---

July 28, 1990

Twig pply	Twig on	S.V. on	Twig off	S.V. off	Twg dur	S.V.dur	Steam	Stm dur	Interval
???	1101IE	1101IE	1211.15	NR	---	---	1212.50	3m00s	(>2h00m)
---	1300.00	1350.xx	1413.xx	1413.xx	(1h13m)	(23m)	1414.30	1m35s	2h12m45s
1503.55	1512.45	1529.30	1612.xx	1613.xx	(59m)	(44m)	1615.15	7m00s	---

July 29, 1990

Twig pply	Twig on	S.V. on	Twig off	S.V. off	Twg dur	S.V.dur	Steam	Stm dur	Interval
1053.xx	1231.40	1238.20	1446.35	1448.55	134m55s	130m35s	1448.25	1m25s	3h01m50s
---	1533.30	1557.10	1639.40	NR	66m10s	NR	no	---	1h57m25s
---	1730.55	1748.xx	1821.xx	1823.50	(50m)	(35m)	no	---	2h09m15s
---	1940.10	2001.xx	2046.45	2048.50	66m35s	(47m)	no	---	---

October 27, 1990

Twig pply	Twig on	S.V. on	Twig off	S.V. off	Twg dur	S.V.dur	Steam	Stm dur	Interval
---	1746IE	NR	(still IE 1824)		(>38m)	---	---	---	---

October 28, 1990 (MDT)

Twig pply	Twig on	S.V. on	Twig off	S.V. off	Twg dur	S.V.dur	Steam	Stm dur	Interval
1023.20	1346.20	1350.20	1603.20	1605.15	137m00s	134m55s	1606.35	1m25s	3h03m45s
---	1650.05	1711.45	1842.xx	1845.xx	(102m)	(34m)	no	---	---

Raw Data: UNNG-FTN-3

October 27, 1990

Start	Dur	Interval
1750.xx	NR	(16m)
1806.04	16s	(20m)
1826.xx	NR	---

October 28, 1990 (MDT)

Start	Dur	Interval
0933.25	13s	5m23s
0938.48	18s	7m10s
0945.58	21s	45m20s
1031.18	23s	8m02s
1039.20	21s	33m15s
1112.35	22s	29m15s
1141.50	20s	36m57s
1218.47	20s	7m19s
1226.06	19s	25m36s
1251.32	18s	21m23s
1312.55	21s	37m08s
1350.03	19s	14m03s
1404.06	19s	33m23s
1447.29	NR	31m16s
1518.45	22s	25m02s
1543.47	21s	32m19s
1616.06	22s	22m19s
1638.25	21s	18m37s
1657.02	21s	21m29s
1718.31	18s	(29m)
1747.xx	NR	(27m)
1814.21	19s	18m10s
1832.21	NR	(28m)
1900.xx	NR	---

Raw Data: Jet Geyser

May 6, 1990

Preplay	Start	Dur	Intvl	Ftn
NR	1754.xx	NR	(5m)	N
NR	1759.xx	NR	(7m)	N
NR	1806.xx	NR	---	N

May 27, 1990

Preplay	Start	Dur	Intvl	Ftn
NR	1343.00	65s	08.45	N
NR	1351.45	70s	09.55	N
NR	1401.40	55s	---	N
NR	1504.50	NR	03.10	Y
NR	1507.40	NR	02.30	Y
NR	1510.10	22s	01.37	Y
NR	1511.47	8s	01.09	Y
NR	1512.56	30s	00.47	Y
NR	1513.43	21s	03.35	Y
NR	1517.18	19s	01.25	Y
NR	1518.43	24s	01.25	Y
NR	1520.08	(20s)	02.37	Y
NR	1522.45	24s	02.42	Y
NR	1525.27	23s	02.31	Y
NR	1527.58	21s	02.30	Y
NR	1530.28	31s	01.48	Y
NR	1532.16	7s	00.57	Y
NR	1533.13	28s	02.31	Y
NR	1535.44	32s	02.31	Y
NR	1538.15	35s	(3m)	Y
NR	1541.xx	NR	---	N

July 1, 1990

Preplay	Start	Dur	Intvl	Ftn
1857.15	1857.49	52s	11.00	N
1908.42	1908.49	62s	08.32	N
1917.18	1917.21	61s	08.50	N
1926.06	1926.11	55s	10.56	N
1937.38	1938.05	57s	08.17	N
1946.16	1946.22	61s	17.21	N
---	2003.43	62s	05.07	N
2008.42	2008.50	50s	07.32	N
2016.14	2016.22	57s	09.32	N
2025.51	2025.54	55s	08.02	N
2033.50	2033.56	58s	19.43	N
---	2053.39	50s	04.33	Y
---	2058.12	28s	02.04	Y
---	2100.16	22s	01.41	Y
---	2101.57	30s	02.00	Y
---	2103.57	5s	01.10	Y
---	2105.07	33s	03.09	Y
---	2108.16	26s	02.47	Y
---	2111.03	NR	02.45	Y
---	2113.48	NR	02.31	Y
---	2116.19	30s	02.46	Y
---	2119.05	25s	01.45	Y
---	2120.50	(15s)	01.16	Y
---	2122.06	26s	01.40	Y
---	2123.46	16s	01.15	Y
---	2125.01	32s	01.46	Y
---	2126.47	18s	01.00	Y
---	2127.47	29s	01.45	Y
---	2129.32	25s	01.34	Y
---	2131.06	26s	01.41	Y
---	2132.47	NR	01.29	Y
---	2134.16	27s	01.46	Y
---	2136.02	20s	01.21	Y
---	2137.23	31s	02.41	Y
---	2140.04	30s	02.29	Y
---	2142.33	31s	02.39	Y
---	2145.12	27s	(>19m)	N

No additional activity by 2204

July 28, 1990

Preplay	Start	Dur	Intvl	Ftn
---	1102.01	64s	10.06	N
---	1112.07	63s	13.57	N
---	1126.04	58s	07.42	N
---	1133.46	59s	10.17	N
---	1144.03	64s	09.09	N
---	1153.12	61s	17.34	N
---	1210.46	67s	05.52	N
1216.30	1216.38	60s	07.49	N
1224.22	1224.29	66s	09.11	N
1233.34	1233.40	58s	07.47	N
---	1241.27	60s	11.59	N
1251.17	1253.26	59s	08.11	N
---	1301.37	53s	07.40	N
---	1309.17	57s	10.37	N
---	1319.54	58s	08.30	N
---	1328.24	56s	08.05	N
---	1336.29	52s	16.57	N
1353.23	1353.32	50s	07.45	N
---	1401.17	61s	08.34	N
---	1409.51	62s	09.51	N
1419.33	1419.42	60s	08.02	N
---	1427.44	60s	09.49	N
---	1437.33	50s	08.37	N
---	1446.10	56s	09.38	N
1455.37	1455.48	48s	10.25	N
1506.08	1506.13	66s	08.32	N
---	1514.45	45s	05.11	Y
1519.58	1520.56	33s	03.56	Y
---	1524.52	33s	02.45	Y
---	1527.37	27s	02.41	Y
---	1530.18	31s	01.39	Y
---	1531.57	26s	01.40	Y
---	1533.37	22s	01.35	Y
---	1535.12	25s	01.44	Y
---	1536.56	19s	01.33	Y
---	1538.29	22s	01.36	Y
---	1540.04	24s	01.37	Y
---	1541.41	22s	01.36	Y
---	1543.17	18s	01.31	Y
---	1544.48	21s	01.33	Y
---	1546.21	18s	01.28	Y
---	1547.49	23s	01.41	Y
---	1549.30	15s	01.16	Y
---	1550.46	33s	01.48	Y
---	1552.34	5s	01.03	Y
---	1553.37	35s	02.34	Y
---	1556.11	27s	02.36	Y
---	1558.47	26s	02.30	Y
---	1601.17	NR	02.56	Y
---	1604.13	27s	(>38m)	N

No additional activity by 1642

July 29, 1990

Preplay	Start	Dur	Intvl	Ftn
No activity from 1051 until...				
---	1127.14	64s	18.55	N
---	1146.09	32s	25.15	N
---	1211.24	68s	07.26	N
---	1218.50	63s	28.25	N
---	1247.15	63s	09.35	N
---	1256.50	59s	19.59	N
1315.xx	1316.49	56s	17.01	N
1333.39	1333.50	54s	05.19	N
---	1347.19	65s	07.58	N
---	1355.17	NR	16.50	N

---	1412.07(55s)08.45			N
---	1420.52	59s	09.23	N
---	1430.15	56s	07.52	N
---	1438.07	62s	09.40	N
---	1447.47	66s	08.55	N
---	1456.42	62s	17.15	N
1513.47	1513.57	59s	14.20	N
1528.04	1528.17	62s	08.56	N
1537.06	1537.13	62s	07.19	N
---	1544.32	67s	08.13	N
---	1552.45	61s	08.23	N
---	1601.08	62s	08.42	N
---	1609.50	65s	08.08	N
---	1617.58	59s	08.56	N
---	1626.54	64s	11.49	N
---	1638.43	55s	16.19	N
---	1655.02	61s	05.46	N
---	1700.48	NR	07.38	N
---	1708.26	65s	07.34	N
1715.46	1716.00	56s	08.37	N
1724.24	1724.37	59s	08.31	N
1733.02	1733.08	59s	09.17	N
1742.02	1742.25	58s	08.16	N
1750.33	1750.41	58s	10.57	N
---	1801.38	60s	08.24	N
---	1810.02	59s	09.05	N
---	1819.07	52s	10.20	N
1829.22	1829.27	61s	06.48	N
---	1836.15	65s	10.05	N
---	1846.20	63s	08.52	N
1855.02	1855.12	59s	09.49	N
1903.48	1905.00	64s	10.04	N
---	1915.04	57s	14.32	N
---	1929.36	67s	10.06	N
---	1939.42	NR	09.21	N
---	1949.03	59s	11.35	N
---	2002.30	62s	21.37	N
---	2024.15	65s	08.25	N
---	2032.40	58s	10.46	N
---	2043.26	63s	---	N

October 27, 1990

Preplay	Start	Dur	Intvl	Ftn
---	1753.55	56s	05.56	N
1759.40	1759.51	51s	21.05	N
1813.17	---	---	---	
1820.41	1820.56	57s	---	N

October 28, 1990 (MDT)

Preplay	Start	Dur	Intvl	Ftn
No activity from 0842 until...				
---	1211.15	58s	09.24	N
---	1220.39	54s	90.50	N
1249.42	---	---	---	
1304.54	---	---	---	
1351.11	1351.29	55s	26.56	N
1404.07	---	---	---	
---	1428.25	68s	06.36	N
---	1435.01	65s	15.52	N
1450.39	1450.53	52s	23.24	N
1514.54	1515.14	53s	27.14	N
1541.19	1541.31	51s	10.00	N
---	1551.31	52s	15.52	N
---	1607.23	55s	06.18	N
---	1613.41	50s	09.58	N
1623.34	1623.39	56s	08.15	N
---	1631.54	57s	08.59	N
1640.42	1640.53	52s	17.57	N
1658.44	1658.50	53s	08.32	N
1707.12	1707.22	50s	06.47	N
1720.58	1721.09	52s	16.00	N
---	1737.09	50s	06.47	N
---	1743.56	58s	14.34	N
---	1758.30	NR	10.25	N
1808.47	1808.55	57s	23.23	N
1819.14	---	---	---	
1822.39	---	---	---	
1828.57	1832.18	58s	08.37	N
---	1840.55	59s	20.30	N
---	1901.25	64s	---	N

Raw Data: Spasm Geyser

May 27, 1990

Time	Status
1340	I.E.
1343	End
1345	Crater Empty

July 1, 1990

Time	Status
1841	I.E.
2029	End
2039	Crater Empty
2115	Flooded by Ftn. runoff

July 27, 1990

Time	Status
2010	Crater empty
2050	No change

July 28, 1990

Time	Status
1102	I.E.
1516	End (flooded by Ftn.)
1612	Crater empty

July 29, 1990

Time	Status
1051	I.E.
2051	No change

July 30, 1990

Time	Status
0905	Crater empty

October 27, 1990

Time	Status
1746	Crater empty
1824	No change

October 28, 1990

Time	Status
0842	Crater empty
1310	Start
1324	First overflow
1737	End

Raw Data: "Bearclaw" Geyser

July 1, 1990

Nfill	Wfill	Efill	N on	W on	N off	W off	Ndrn	Wdrn	Edrn	Ndur	Nintvl	Ftn	Twig
NR	NR	NR	1849.40	49.50	51.15	51.20	NR	NR	52.40	1.25	22.30	N	N
(full by1911.32)			1912.10	13.02	15.32	15.30	15.33	15.33	16.40	3.22	30.40	N	N
1942.10	42.19	42.48	42.50	43.42	46.10	46.00	46.02	46.15	47.05	3.20	38.03	N	Y
2019.55	20.15	20.35	20.53	21.33	23.38	23.21	23.33	23.41	24.24	2.45	48.58	N	Y
NR	NR	NR	2109.51	10.26	14.41	14.24	14.36	14.32	13.04	4.50	11.24	Y	N
NR	NR	NR	2121.15	21.31	26.37	26.16	25.42	26.18	26.40	5.22	11.25	Y	N
NR	NR	NR	2132.40	33.12	37.04	37.11	36.32	37.12	37.20	4.24	(12m)	Y	N
NR	NR	NR	2144.xx	44.xx	48.25	48.24	48.10	48.25	48.45	(4m)	(>20m)	N	N

No further activity before 2204

July 27, 1990

Nfill	Wfill	Efill	N on	W on	N off	W off	Ndrn	Wdrn	Edrn	Ndur	Nintvl	Ftn	Twig
(full by 2028)			2028.38	28.55	31.49	31.25	31.19	31.53	32.05	3.11	---	N	N

July 28, 1990

Nfill	Wfill	Efill	N on	W on	N off	W off	Ndrn	Wdrn	Edrn	Ndur	Nintvl	Ftn	Twig
1125.30	25.57	26.20	26.02	26.44	28.30	28.02	28.03	28.26	28.50	2.28	44.02	N	Y
1209.26	09.13	09.57	10.04	10.31	12.36	12.15	12.14	12.39	13.03	2.32	29.45	N	Y
1239.25	39.10	39.47	39.49	40.15	42.29	42.40	42.16	42.48	43.13	2.40	25.58	N	N
1304.38	04.33	05.01	05.47	06.17	08.21	08.09	08.08	08.31	09.04	2.33	42.43	N	Y
1347.38	47.12	47.44	48.30	39.04	50.30	50.15	50.18	50.36	51.01	2.00	(45m)	N	Y
1432.54	32.13	NR	NR	NR	NR	NR	NR	NR	NR	NR	(24m)	N	N
NR	NR	NR	1457.xx	NR	NR	NR	NR	NR	NR	(2½m)	(30m)	N	N
1526.53	26.58	27.05	27.27	28.08	31.40	31.18	31.20	31.52	32.02	3.13	11.32	Y	Y
1538.55	38.51	39.10	38.59	39.29	45.06	44.53	44.55	45.11	45.18	6.07	11.44	Y	Y
1551.12	51.08	51.38	50.43	50.56	55.40	55.23	54.58	55.56	55.07	4.57	10.53	Y	Y
1602.05	01.55	02.26	01.36	01.45	06.11	06.06	05.32	06.47	05.20	4.35	(11m)	Y	Y
NR	NR	NR	1612IE		14.51	14.59	14.32	15.14	14.15	NR	(>30m)	N	N

No further activity before 1642

July 29, 1990

Nfill	Wfill	Efill	N on	W on	N off	W off	Ndrn	Wdrn	Edrn	Ndur	Nintvl	Ftn	Twig
1109.39	09.23	09.47	10.30	10.54	13.14	12.55	12.47	13.18	13.59	2.44	27.47	N	N
1137.43	37.30	37.40	38.17	38.37	41.26	40.50	40.48	41.24	41.57	3.09	26.49	N	N
1204.16	04.04	04.33	05.06	05.25	07.40	08.03	07.39	08.09	08.46	2.34	25.43	N	N
1230.03	29.43	30.09	30.49	31.14	33.35	NR	33.33	33.58	34.24	2.46	40.59	N	N
1311.09	10.22	10.55	11.48	12.10	14.22	13.58	13.56	14.16	14.42	2.34	46.35	N	Y
1357.49	57.07	57.37	58.23	58.56	00.25	59.56	59.55	00.16	00.34	2.02	24.01	N	Y
1441.56	41.32	41.41	42.24	43.04	44.58	44.37	44.35	44.59	45.26	2.34	28.06	N	Y
NR	NR	NR	1510.30	10.57	13.53	13.28	13.26	13.50	14.27	3.23	26.07	N	N
1535.40	35.22	35.38	36.37	36.54	39.15	38.52	38.51	39.20	39.54	2.38	41.42	N	Y
1617.27	17.07	17.15	18.19	18.51	20.49	20.22	20.20	20.41	21.12	2.30	36.07	N	Y
1653.42	53.05	53.24	54.26	54.48	56.44	56.25	56.22	56.42	57.21	2.18	26.19	N	N
1719.44	19.33	19.50	20.47	21.15	23.10	22.57	22.56	23.21	23.58	2.23	43.05	N	N
1802.47	02.24	02.38	03.52	04.16	05.43	05.24	05.23	05.48	06.16	1.51	41.45	N	Y
1844.54	44.14	44.29	45.37	46.14	48.04	47.42	47.41	48.08	48.40	2.27	55.08	N	N
NR	NR	NR	1941.45	42.20	44.30	44.10	44.08	44.42	45.06	2.45	33.03	N	Y
2013.31	12.56	13.13	14.48	15.20	16.43	16.15	16.13	16.39	17.04	1.55	28.01	N	Y
NR	NR	NR	2042.49	43.31	NR	45.16	45.15	45.38	46.03	NR	---	N	N

October 27, 1990

Nfill	Wfill	Efill	N on	W on	N off	W off	Ndrn	Wdrn	Edrn	Ndur	Nintvl	Ftn	Twig
NR	NR	NR	1751.32	52.11	53.10	53.01	53.21	53.44	54.27	1.28	---	N	Y

October 28, 1990 (MDT)

Nfill	Wfill	Efill	N on	W on	N off	W off	Ndrn	Wdrn	Edrn	Ndur	Nintvl	Ftn	Twig
NR	NR	NR	(0952IE)		54.02	53.56	NR	54.08	54.14	NR	(26m)	N	N
0919.09	18.41	19.16	18.01	18.24	20.32	20.18	20.07	20.32	20.25	2.31	35.21	N	N
0953.54	54.02	54.00	53.20	54.22	56.03	56.14	55.54	56.17	56.26	2.43	32.18	N	N
1025.27	25.07	25.22	25.38	25.54	28.03	27.54	27.43	28.13	28.39	2.25	31.04	N	N
1055.47	56.00	56.08	56.42	57.11	58.46	58.41	58.50	59.15	59.53	2.04	30.44	N	N
1126.20	26.23	26.30	27.26	27.53	29.28	29.30	29.37	29.58	30.53	2.02	27.05	N	N
1152.54	53.02	53.11	54.31	55.12	56.17	56.16	56.21	56.44	57.35	1.46	27.18	N	N
1220.22	20.25	20.33	21.49	22.43	23.56	23.53	23.59	24.22	25.21	2.07	26.31	N	N
1246.31	46.42	NR	48.20	49.01	50.17	50.14	50.19	50.44	51.33	1.53	26.21	N	N
NR	NR	NR	1314.41	15.13	16.32	16.34	16.39	17.02	17.58	1.52	25.03	N	N
1338.20	38.26	38.33	39.44	40.23	42.18	42.20	42.23	42.43	43.32	2.34	37.57	N	N
1415.43	15.49	15.53	17.11	17.50	19.09	19.03	19.13	19.40	20.32	1.58	47.19	N	Y
1500.45	00.55	00.57	02.30	03.27	03.58	03.57	04.02	04.23	05.16	2.28	40.08	N	Y
1540.54	40.57	41.02	42.38	43.36	44.16	44.12	44.21	44.42	45.38	1.38	36.57	N	Y
1617.47	17.53	18.02	19.35	20.47	21.16	21.19	21.22	21.42	22.39	1.41	24.50	N	N
1642.38	42.34	42.41	44.25	45.31	46.24	46.21	46.28	46.56	47.33	1.59	33.30	N	N
1716.08	16.12	NR	17.55	19.01	19.02	19.29	19.38	19.57	20.45	1.07	39.19	N	Y
1755.23	55.29	55.37	57.14	58.22	NR	NR	58.52	59.06	59.51	NR	(37m)	N	Y
NR	NR	NR	(1834IE)		NR	NR	NR	NR	NR	NR	(30M)	N	Y
NR	NR	NR	(1904IE)		NR	NR	NR	NR	NR	NR	---	N	N

1991 ACTIVITY OF MORNING GEYSER AND OTHER FEATURES IN THE FOUNTAIN COMPLEX PART I, May 4 and 5, 1991

by Lynn Stephens

ABSTRACT: After eight year's of dormancy, Morning Geyser reactivated during the 1991 season. There were three observed periods of activity--one on May 4 and 5 with five known solo eruptions of Morning, one on July 4 and 5 with two concerted eruptions of Fountain and Morning, and one from August 9-29 that started with a concerted eruption of Fountain and Morning, was followed by 118 known solo eruptions of Morning, and concluded with two concerted eruptions of Fountain and Morning. This report describes the activity of Morning Geyser and other features in the Fountain Complex on May 4 and 5, 1991. (July and August activity are described in other reports.)

INTRODUCTION:

Lee Whittlesey reported that Morning Geyser was in eruption at 0938 on May 4, 1991. The eruption ended at 0950, a duration exceeding 18 minutes. Morning erupted again at 1338 (period approximately 4 hours, duration 16 minutes), 1717 (period 3 hours 39 minutes, duration 18 minutes), 2135 (period 4 hours 18 minutes, duration 17 minutes), and 0025 on May 5 (period 2 hours 50 minutes, duration 18 minutes). Fountain erupted at 1723 on May 5, signally what turned out to be the end of Morning's activity until July.

Rick Hutchinson replaced the marker on Morning at 1055 and stated that since the water in Morning was clear, this was probably not the first eruption. Based on the information that the water level in Morning was over 1 meter below ground level, that in the past Morning had been overflowing into Fountain before Morning erupted, and that it took several hours for Morning to reach overflow, the few gazers in the park left the area thinking that there was plenty of time to get organized for a session of waiting.

Later, Robert and Nancy Bower were on their way to Norris and stopped at the Fountain Complex. They walked up, noted Morning was not overflowing, and Morning erupted three minutes later, at 1338.

Mike Keller, Jens Day, and I kept the area under almost continuous observation from 1400 May 4 until the end of the Fountain eruption that started on May 5 at 1723. This report describes our observations of geysers in the Fountain Complex and how their activity showed one pattern while Morning was active, and a different pattern while the energy was shifting to Fountain.

In this report, the term "period" rather than "interval" is used for the span of time from the start of one eruption to the start of the next eruption [Bryan, 1992].

TWIG AND TWIG'S SATELLITE VENTS:

Twig was in eruption at 1040 on May 4, stopped sometime between 1130 and 1400, and did not erupt again until 0419 on May 5, a quiet time of more than 14 hours. This eruption had a duration of 2 hours 36 minutes. Twig erupted next at 0734, a period of 3 hours 15 minutes, and the eruption lasted 1 hour 17 minutes. Twig then erupted at 0928, 1059, 1240, 1518, and 1645. The periods between these eruptions ranged from 1 hours 27 minutes to 2 hours 38 minutes. The 0928 and 1059 eruptions each had durations of 50 minutes. Durations for the other eruptions were not noted.

In summary, Twig was active for the first observed eruption of Morning, quiet during the remainder of Morning's activity, seemed to show a period of recovery with a relatively long duration for the 0419 eruption, and then had a series of shorter periods and durations while the energy was shifting from Morning back to Fountain. The frequency with which Twig erupted on May 5 was not noted again during the 1991 season, despite the fact that many hours were spent in July and August monitoring the Fountain Complex.

Times were taken for Twig's Satellite Vents from 1400 until 2135 on 5/4/91. The average for the 24 consecutive periods was 12 minutes, with a range of 11 to 14 minutes. Thirteen durations were timed, all of which lasted five minutes. Frequent observations of Twig's Satellite Vents were not made again until 0700 May 5. For the next three hours, the periods ranged from 27 to 38 minutes. Durations were irregular, ranging from 3 minutes to 11 minutes.

Thus, the activity pattern did change sometime between 2135 on May 4 and 0700 on May 5, but not enough is known about the relationships between Twig's Satellite Vents and other geysers in the complex to speculate whether this change in activity was correlated with the change in Twig's activity, with the shift in energy from Morning back to Fountain, or was unrelated to either of these factors.

UNGFTN2 AND JET:

UNGFTN2: During the period Morning was active, three eruptions of UNGFTN2 were observed, with periods between the eruptions of 3 hours 58 minutes and 3 hours 29 minutes. Because each of the eruptions of UNGFTN2 was followed by an eruption of Morning, with no intervening eruptions of Jet, we noted that UNGFTN2 seemed to act as an indicator for Morning. As with Beehive's Indicator, the length of time between the starts of UNGFTN2 and Morning was variable, with lead times of 22 minutes before the 1717 eruption of Morning, 42 minutes before the 2135 eruption of Morning, and 3 minutes before the 0025 eruption of Morning.

After the 0022 May 5 eruption of UNGFTN2, the time between eruptions shortened. Seven periods were observed between the 0022 May 5 eruption and Fountain's eruption at 1723. These averaged 2 hours 25 minutes, with a range from 44 minutes (the period immediately preceding Fountain's eruption) to 3 hours 7 minutes (the only period exceeding 3 hours).

Although the time between UNGFTN2 eruptions shortened, the duration of UNGFTN2 eruptions did not change. Durations were noted for nine of the ten eruptions of UNGFTN2 that occurred between 1540 on May 4 and 1723 on May 5; all were either 14 or 15 minutes.

Jet: Jet's activity on May 4 and 5 consisted of series of eruptions, with each series ended by an eruption of UNGFTN2 and a quiet spell for Jet. Two differences between Jet's pattern of activity before and after Morning's activity ended were noted. First, the quiet spell between the end of one series and the beginning of the next series shortened. Second, times between Jet eruptions within a series lengthened.

Timing of Jet began at 1540 on May 4, when Jet was in the middle of a series of eruptions. From 1540 to 1651, Jet's periods averaged seven and a half minutes, and ranged from seven to nine minutes. UNGFTN2 erupted at 1655. Jet was then quiet for 59 minutes.

The next series started at 1750 and ended at 2049. There were 30 eruptions of Jet in the series, resulting in 29 closed periods. These periods ranged from five to nine minutes in length. Of the first 15 periods, eight were five minutes long, five were six minutes, and two were seven minutes. Of the last 14 periods, one was five minutes, five were six minutes, five were seven minutes, two were eight minutes, and one was nine minutes. UNGFTN2 started at 2053, ending this series of Jet eruptions. Jet was then quiet for 68 minutes.

Jet was not under observation from 2157 to 2320. When timing resumed at 2320, Jet's periods exhibited greater variation. The first four were 5 minutes, 7 minutes, 5 minutes, and 9 minutes. The next one was 16 minutes, and it was followed by an 11 minute period, with the final Jet eruption in the series occurring at 0018 on 5/5/91. UNGFTN2 erupted at 0022.

Jet's next series started at 0112, following a quiet period of 54 minutes. The first five periods were between six and eight minutes in length. No further data was collected on this series of eruption.

UNGFTN2 erupted at 0309, and Jet started its next series at 0345, a quiet time exceeding 36 minutes, but probably less than 40 minutes. During the Jet series from 0345 to 0549, there were 14 Jet eruptions. The time between eruptions ranged from eight to 11 minutes, with the exception of one 15 minute period.

The next Jet series began at 0627, after 36 minutes of quiet, and ended at 0807. The times between the 12 Jet eruptions ranged from eight to ten minutes. Following 35 minutes of no eruptions, the next series started at 0842 and ended at 1033. The 11 periods between Jet eruptions in this series ranged from eight to 13 minutes. A quiet spell of 39 minutes preceded the start of the next Jet series at 1112. The first four periods in this series were nine and 10 minutes in length.

Data on Jet from 1150 to 1535 is not available. From

1535 to 1629, five eruptions resulting in three consecutive periods of 9, 12, and 14 minutes were observed. The series ended with an eruption of UNGFTN2 at 1632. Interestingly, Jet resumed eruptions at 1647, after only 18 minutes of quiet. Three periods of 5, 9, and 13 minutes occurred before the start of Fountain's eruption. Jet erupted near the start of Fountain's eruption, a period of 9 minutes, erupted again 5 minutes later, and then began erupting every 2-3 minutes.

For each of the Jet series, the time between the last Jet and the start of UNGFTN2's eruptions was between two and four minutes.

With the exception of the two long intervals immediately prior to the 0022 eruption of UNGFTN2, the time between Jet eruptions in a series ranged from five to nine minutes during the period of Morning's activity. After the 0309 eruption of UNGFTN2, the time between Jet eruptions in a series gradually lengthened from 8 to 11 minutes, then to 9 to 13 minutes. The length of the quiet period between series shortened from 60-70 minutes while Morning was active to 35-40 minutes during the energy shift to Fountain, and then to 18 minutes just before Fountain erupted.

JELLY:

Jens Day first noted Jelly in eruption at 1320 on May 5. This eruption consisted of minor activity to 1/3 meter. He reported a major eruption of 3 meters at 1500, a major at approximately 1540, a major to 5 meters at 1614, a major at 1650 with a duration of 1 minutes 30 seconds, and a major at 1714. This is the only known eruptive activity of Jelly during the 1991 season.

CLEPSYDRA:

Clepsydra was in constant eruption from 1400 on May 4 until 1726 on May 5. Eruptive activity by Morning did not cause Clepsydra to stop erupting. Clepsydra did stop three minutes after Fountain's eruption started at 1723. Clepsydra restarted at 1740 for a few minutes, then stopped, and restarted at 1838, seven minutes after Fountain ended.

SPASM:

During the time Morning was active, Spasm was quiet before Morning's eruption. During Morning's eruption, Spasm's water level would rise and Spasm would start erupting. The eruption would start with muddy water, which would gradually clear. Following Morning's eruption, Spasm would again drop and then resume eruption during the next eruption of Morning.

It was noted at 0047 that Spasm had started sometime during Morning's 0025 eruption. Sporadic notations between 0047 and 1130 indicated that Spasm was in eruption whenever it was checked. The stop time of this eruption is not known.

FOUNTAIN:

Fountain erupted at 1723 on May 5. The eruption lasted 62 minutes. The eruption was very muddy, and many rocks were thrown out during the eruption.

ERUPTIONS OF MORNING:

The May activity of Morning differed from reports of prior activity in several ways. Periods between eruptions were significantly shorter (the 2 hour 50 minute period is still the shortest known for Morning); durations were shorter (16-18 minutes, compared with reports of 40-60 minutes for other years); the eruptions were not as tall (estimated maximum of 30-40 meters compared to 65 meters in other years); and, Morning was not overflowing into Fountain prior to the start of each eruption. (As with all statements about geyser activity, there are exceptions. Marler [1973] noted that Morning erupted at intervals of a few hours from a nonoverflowing pool during the 1957 season and possibly the 1958 seasons.)

Prior to each eruption of Morning, the water level would gradually rise, as determined by using various rocks in the crater, but did not reach overflow stage. Then, with no visible warning, the water level would suddenly surge, sending waves across the surface of the crater. Within seconds, Morning would have a preliminary burst of 3-5 meters, and then the bursts would start. We estimated that there was one burst approaching 40 meters in the 1717 eruption. The 2135 eruption was the "weakest" of the three we witnessed. Rick Hutchinson estimated there was only one burst of 30 meters. The 0025 eruption seemed to be the strongest. Almost every burst was preceded by the pop-boom sound we associated with the larger bursts of the prior eruptions. The 0025 eruption poured an almost constant flood of water into Fountain, more than the other two eruptions had. Several of the bursts threw water to the south edge of Fountain's crater. Activity during the second half of the eruption seemed to be stronger than activity during the first half of the eruption.

Since we had been told that it was sometimes possible to hear audible thumps during Morning's eruptions, we made an effort to listen for them during the 2135 and 0025 eruptions. Although people were generally quiet during the 2135 eruption and Jens and I were the only people at the 0025 eruption, we did not hear any thumps.

The only eruption I saw during full daylight was the 1717 eruption, which was the first eruption of Morning I had seen. I have no better words to describe it than the description that others have used--it looks like the 1880's photos of Excelsior, only on a smaller scale. The first draft of this report, written in May 1991, concluded with a statement that I hoped to see Morning again in 1991. That wish came true in July, and again in August, and the activity is described in separate reports.

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Bryan, T. Scott. TIPS FOR GEYSER GAZERS #1 DOCUMENTING THE TIME AND APPEARANCE OF GEYSER ERUPTIONS, 1992.

Marler, George. INVENTORY OF THERMAL FEATURES OF THE FIREHOLE RIVER GEYSER BASINS, AND OTHER SELECTED AREAS OF YELLOWSTONE NATIONAL PARK. NTIS Pub. PB221289, 1973.

FOUNTAIN COMPLEX, May 4-5, 1991

May 4, 1991

Jet	Period (P)	UNGFTN2	Twig's Sat. Vents	Other
1542				
1549	7m		1551, d = 5m	
1556	7m		1603, P=12m, d = 5m	
1604	8m			
1611	7m		1615, P=12m, d = 5m	
1618	7m			
1626	8m		1627, P=12m, d = 5m	
1634	8m		1639, P=12m	
1643	9m			
1651	8m		1651, P=12m	
		1655, d=14m		
			1703, P=12m	
				Morning: 1717, d = 18m, P = 3hr 39m
1750	59m		1755	
1756	6m			
1801	5m			
1808	7m		1809, P=14m, d = 5m	
1814	6m			
1819	5m		1822, P=13m, d = 5m	
1824	5m			
1830	6m		1833, P=11m, d = 5m	
1836	6m			
1842	6m		1845, P=12m, d = 5m	
1849	7m			
1854	5m		1856, P=11m, d = 5m	
1859	5m			
1904	5m		1908, P=12m, d = 5m	
1909	5m			
1914	5m		1919, P=11m, d = 5m	
1921	7m			
1927	6m		1931, P=12m, d = 5m	
1934	7m			
1939	5m		1943, P=12m, d = 5m	
1945	6m			
1952	7m		1954, P=11m	
2001	9m		2006, P=12m	
2009	8m			
2015	6m		2017, P=11m	
2022	7m			
2028	6m		2029, P=12m	
2034	6m		2041, P=12m	
2042	8m			
2049	7m		2052, P=11m	
		2053, d = 14m, P = 3 hr 58m		
			2105, P=13m	
			2117, P=12m	

Fountain Complex, May 4, 1991 (continued)

Jet	Period	UNGFTN2	Twig's Sat. Vents	Other
			2129, P=12m	
				Morning: 2135, d = 17m P = 4hr 18m
2157	68m			
------------------------Break in data------------------------				
2323				
2328	5m			
2335	7m			
2342	7m			
2351	9m			
		May 5, 1991		
0007	16m			
0018	11m			
		0022, P = 3hr 29m, d = unk.		
				Morning: 0025, d = 18m, P = 2hr 50m
0112	54m		0113ie	
0119	7m			
0127	8m		0128ie	
0133	6m			
------------------------Break in data------------------------				
		0309, P = 2hrs 48m, d = 15m		
0345				
0355	10m			
0404	9m			
0414	10m			Twig: 0419, d = 2 hr 36m
0422	8m			
0430	8m			
0438	8m			
0446	8m			
0454	8m			
0509	15m			
0517	8m			
0528	11m			
0539	11m			
0549	10m			
		0553, P= 2hr 44m, d = 14m		
0625	36m			
0634	9m			
0644	10m			
0653	9m			
0703	10m		0706ie	
0712	9m			
0720	8m		0729, d = 3m	
0730	10m			Twig: 0734, d = 1 hr 17m, P = 3hr 15m
0739	9m			
0749	10m			
0758	9m			

Fountain Complex, May 5, 1991 (continued)

Jet	Period	UNGFTN2	Twig's Sat. Vents	Other
0807	9m		0807, P = 38m, d = 11m	
		0812, P = 2hr 19m, d = 15m		
0842	35m		0844, P = 37m	
0850	8m			
0859	9m			
0910	11m		0911ie, P = app. 27m	
0920	10			Twig: 0928,
0929	9m			d = 50m,
0937	9m			P = 1hr 54m
0946	9m		missed one	
0959	13m			
1010	11m		1011	
1020	11m			
1033	13m			
		1037, P = 2hr 25m, d = 14m		
			1038, P = 27m	
				Twig: 1059,
				d = 50m,
				P = 1hr 31m
1112	39m			
1121	9m			
1130	9m			
1140	10m			
1150	10m			

Information provided by Jens Day:

Jet	Period	UNGFTN2	Twig's Sat. Vents	Other
				Twig: 1240
		1344, P = 3hr 7m		
				Twig: 1518
1535				
1554				
1603	9m			
1615	12m			
1629	14m			
		1632, d = 14m, P = 2hr 48m		
				Twig: 1645
1647	18m			
1652	5m			
1701	9m			
1714	13m	1716, P = 44m		
1723	9m			Fountain: 1723,
1728	5m			d = 62m, Clepsydra
1731	3m			stop 1726, start 1740
1734	3m			for a few minutes,
				start 1838.

Jelly: 1320ie minors to 12inches; 1500 major 10 ft; app. 1540 major; 1614 major 15 ft; 1650 major (d=1m30s); 1714 major.

1991 ACTIVITY OF MORNING GEYSER AND OTHER FEATURES IN THE FOUNTAIN COMPLEX PART II, July 4-7, 1991

by Lynn Stephens

ABSTRACT: Morning and Fountain geysers erupted in concert on July 4 and again on July 5, 1991. This report describes activity of geysers in the Fountain Complex for July 4 through 7, and compares the activity patterns during this time with those observed during the May 4 and 5, 1991, activity of Morning.

INTRODUCTION:

Morning Geyser erupted on July 4, 1991, at 1442 and again on July 5, 1991, at 1345, a period of 23 hours 3 minutes. The July 4 eruption was the first eruption of Morning since the 0025 May 5, 1991, eruption, a period of 60 days, 14 hours, and 17 minutes. Both the July 4 and July 5 eruptions were concerted eruptions with Fountain Geyser, an event which is only known to have happened once before--after the August 17, 1959, earthquake. The July 4 concerted eruption was witnessed (and filmed) by Tom and Genean Dunn, and Karl and Jessie Bender. Tom Dunn reported that Fountain initiated the eruption at 1440, with Morning following two minutes later. Morning's eruption lasted 31 minutes; Fountain's eruption lasted 95 minutes. A number of geyser gazers were on hand for the July 5 concerted eruption. Fountain initiated the action at 1343, and Morning followed at 1345. Morning's duration was 21 minutes; Fountain's duration was 82 minutes. Fountain is known to have had at least one, but probably only one, solo eruption between the two concerted eruptions.

This report summarizes observations of the Fountain Complex from July 4-7, 1991. The area was under observation during the following times: July 4--1330-2330; July 5--0620-1430 and 1925-2350; July 6--0338-1415; and July 7--0540-0630 and 0720-0935.

This report also compares activity of selected features within the Fountain Complex during the May 4-5, 1991, and July 4-5, 1991, active periods of Morning. Two objective similarities were noted--(1) Jet's intervals within a series lengthened after the completion of Morning's eruptive activity, and (2) Twig did not erupt during the period of Morning's activity. A third, less objective, similarity was that the water levels in Fountain and Morning reached a higher level prior to Fountain's eruption after Morning's activity had ceased than the water levels did between eruptions while Morning was still active.

Dissimilarities were also noted: (1) the regularity of eruptions by Twig's Satellite activity was not present during the July activity; (2) the pattern of each UNGFTN2 eruption being followed by an eruption of Morning was not repeated; and, (3) Fountain had a solo eruption between the two concerted eruptions while the solo eruption of Fountain on May 5 was followed by a two month period of inactivity by Morning.

TWIG AND TWIG'S SATELLITE VENTS:

A similarity between the May 1991 and July 1991 active episodes of Morning was the lack of eruptive activity by Twig between the eruptions of Morning. The 0918 July 6 eruption of Twig occurred after a period exceeding 27 hours. (Although this eruption was the first known eruption since before 1750 July 4, markers were not placed on Twig between 2330 July 4 and 0620 July 5 so it could not be determined if an eruption occurred during that period.) The 0918 July 6 eruption had a duration of 3 hours 32 minutes, comparable to the first Twig eruption following the cessation of Morning's activity in early May. The succeeding period of Twig was not determined, but was in excess of 5 hours, unlike early May, when the succeeding period was 3 hours 15 minutes.

Periods for Twig's Satellite Vents did not show any regularity on July 4 and July 5. Closed periods on July 5 ranged from a 11 to 51 minutes, with durations of 2-4 minutes. Regularity appeared on July 6 when periods ranged from 26-30 minutes, with durations of 2-5 minutes. Three consecutive periods of 45, 39, and 33 minutes were observed on July 7. This was the reverse of the May pattern when periods were regular at close to 12 minutes and durations were constant at 5 minutes while Morning was active and irregularity appeared after Morning's activity ceased.

JET AND UNGFTN2:

Underground connections between Jet and UNGFTN2 ("Super Frying Pan") are evidenced by the long interval between Jet eruptions that usually occurs following an eruption by UNGFTN2. This long interval is used to define a series of Jet eruptions, i.e., each eruption of UNGFTN2 and subsequent quiet period for Jet separates a series. Jet's eruptions were timed beginning with first water. Jet's eruptions, particularly those at the beginning of a series, are sometimes preceded by rumbling noises. Although exact times of the duration of the noise preceding water were not taken, it was noted that the time does vary. Rumbling sounds precede the first eruption in a series for much longer than they do for eruptions within a series.

Jet: The Dunns and Benders reported the following observations for Jet from 2000-2236 on July 3: "Jet had a series of nine eruptions with an average period of 9.67 minutes prior to a 14-minute play of UNGFTN2. Twenty-four minutes after UNGFTN2 stopped, Jet resumed with a series of 6 periods of 6.83 minutes on the average." The quiet spell for Jet was about 38 minutes--the 14 minutes during which UNGFTN2 was in eruption plus the 24 minutes after it stopped. The duration of Jet's quiet spell is comparable to quiet spells during the period of energy shift from Morning back to Fountain on May 5 as opposed to the 60-70 minute quiet spells observed while Morning was active on May 4.

Their observations for Jet and UNGFTN2 on July 4 prior to the Morning and Fountain concerted eruptions were: "Jet erupted at 1342 and 1349, followed by an eruption of UNGFTN2 at 1353. This eruption lasted 13 minutes until 1406. Jet returned to play at 1428 and 1434 prior to the initiation of Fountain at 1440 and Morning at 1442." The quiet spell was 39 minutes, again comparable to the May energy shift period.

Regarding Jet and UNGFTN2's activity during the July 4 concerted eruption, they stated: "Soon after Morning stopped [1513], Jet and UNGFTN2 began to play simultaneously at 1530. Jet was larger than normal reaching an estimated 8-9 meters from the top vents. Jet stopped playing after approximately one minute and played again at 1535 while UNGFTN2 continued."

Observations of the Fountain Complex during the last two weeks of July showed that an eruption of UNGFTN2 was followed by a quiet spell for Jet if Fountain was not in eruption when UNGFTN2 started, even if Fountain started during UNGFTN2's eruption. However, if Fountain erupted while Jet was in a series of eruptions, and then UNGFTN2 started erupting, Jet would continue erupting.

On the other hand, during the three weeks in August that Morning was erupting solo, simultaneous eruptions of Jet and UNGFTN2 were observed when Morning was <u>not</u> in eruption, rather than when Morning was in eruption.

This indicates that the simultaneous eruptions of Jet and UNGFTN2 on July 4 were related to the Fountain eruption rather than the Morning eruption, particularly since the simultaneous eruptions occurred after Morning stopped.

Jet's eruptive series on July 4 continued until 1738, 83 minutes after the stop of Fountain. Jet was then inactive for a period of almost 5 hours, not resuming eruptions until the start of the 2226 Fountain eruption. Jet erupted at 2-3 minute intervals during Fountain's 2226 eruption.

On July 5, 1991, Jet's periods within a series generally ranged from 6-8 minutes, while periods between a series were approximately 40 minutes. Of 51 periods within three series between 0619 and the concerted eruption of Morning and Fountain at 1343, only seven periods were above the 6-8 minute range.

During the concerted eruption of Morning and Fountain, Jet erupted at 1-2 minute intervals, and erupted simultaneously with UNGFTN2. Again, Fountain started, then UNGFTN2 started, so Jet was able to erupt simultaneously with UNGFTN2. The difference between July 4 and July 5 is that this simultaneous activity of Jet and

UNGFTN2 occurred while Morning was still erupting. As previously noted it is Fountain's activity rather than Morning's activity during their concerted eruption that allows this to happen. The time Jet's eruptions ceased was not noted.

Jet exhibited a long period of noneruptive status that started before 1925 and ended at 2311 that evening.

On July 6, 1991, Jet's periods within a series lengthened. Only 13 of the 20 periods in the first series (0436-0706) were between 6-8 minutes; the other seven periods were 8-9 minutes. In the second series, only three of the 18 periods were 6-8 minutes and the remaining 15 were between 8-10 minutes. For the third series (1054-1302), there were no periods less than seven minutes, five periods of seven minutes, three periods of eight minutes, four periods of nine minutes, and two periods exceeding nine minutes. Jet's quiet spell between series remained at approximately 40 minutes.

This change in the pattern of Jet's intervals that seems to occur after Morning has ceased eruptive potential is similar to what happened on May 5, 1991. Whether this is a result of a shift of energy away from Morning, an indication that the shift is about to occur, or is unrelated to activity in Morning is not known. Two observation periods are only enough to raise speculations, not sufficient for drawing conclusions.

UNGFTN2: Each of the three eruptions of UNGFTN2 during the period of Morning's activity May 4-5, 1991, were followed by eruptions of Morning, but this did not happen in July. In May, I stated that UNGFTN2 seemed to act as an indicator for Morning. When I wrote the first version of this report in July 1991, I stated: "That [indicator activity] now appears to have been merely a coincidence where two geysers erupting (at that time) on approximately 3 hour intervals converged." But then in August UNGFTN2 again seemed to act as an indicator for Morning for the first few solo eruption of Morning. Now the question is: When Morning is erupting at about 4 hour periods from a nonoverflowing pool, does UNGFTN2 appear to act as indicator for Morning, and if so, how long does this behavior persist after the start of Morning's eruptions?

The Dunns and Benders reported that UNGFTN2 erupted at 1353 on July 4 prior to the concerted Morning and Fountain eruption, and then again at 1530 after Morning had stopped but while Fountain was still erupting. The period between these two eruptions was 1 hour 37 minutes. Jet was active prior to the beginning of this period, stopped for a quiet spell after UNGFTN2 started, resumed eruptions, then stopped while Morning erupted, and resumed activity after Morning finished.

The next period for UNGFTN2 was 3 hours 38 minutes. Jet was active during the first 2 hours 8 minutes of this period and active during the first 2 hours 8 minutes of this period and inactive during the remaining 1 hour 30 minutes.

The next two periods for UNGFTN2 prior to the 2226 solo eruption of Fountain were 1 hour 58 minutes, and 1 hour 35 minutes. Jet was quiet during this time.

One closed period of 2 hours 41 minutes was obtained on the morning of July 5 for UNGFTN2. Jet was active during this time. Then, Fountain started at 1343, Morning started at 1345, and UNGFTN2 started sometime between 1343 and 1346. The period for UNGFTN2 was approximately 2 hours 30 minutes, with Jet active during this time.

The Fountain Complex was not under observation from 1530 to 1925 on July 5, but was observed from 1925 to 2345. UNGFTN2 erupted at 2031 and 2218, a period of 1 hour 47 minutes. Jet was quiet from 1925 to 2311.

The Fountain Complex was observed from 0335 to 1430 on July 6. Three consecutive periods of 3 hours 2 minutes, 3 hours 12 minutes, and 2 hours 44 minutes were recorded. Jet was active during these periods.

A review of the July data on periods for UNGFTN2 indicates that the length of the periods depended on whether or not Jet was active (Table 1.) When Jet was active, periods were 2 1/4 to 3 1/4 hours; when Jet was inactive, periods were 1 1/2 to 2 hours. But the data for May indicated the possibility that periods were shorter as the energy shifted back to Fountain than they had been when Morning was active. Further observations are needed to determine whether activity status of Jet fully explains the change in periods, or whether the position of energy in the group with respect to Fountain or Morning also contributes to explaining variability in the length of the periods.

TABLE 1

UNGFTN2 PERIODS AND JET

Date	Time	UNGFTN2 Period	Jet Active
5/4	1655		Yes
	2053	3 hr 58 m	Yes
5/5	0022	3 hr 29 m	Yes
	0309	2 hr 48 m	Yes
	0553	2 hr 44 m	Yes
	0812	2 hr 19 m	Yes
	1037	2 hr 25 m	Yes
	1344	3 hr 7 m	Yes
	1632	2 hr 48 m	Yes
7/4	1353		Yes
	1530	1 hr 37 m	(1)
	1908	3 hr 38 m	(2)
	2058	1 hr 58 m	No
	2233	1 hr 35 m	No
7/5	0834		Yes
	1115	2 hr 41 m	Yes
	1345	2 hr 30 m	Yes
	2031		No
	2218	1 hr 47 m	No
7/6	0408		Yes
	0710	3 hr 2 m	Yes
	1022	3 hr 12 m	Yes
	1306	2 hr 44 m	Yes
7/7	0627		No
	0842	2 hr 15 m	Yes

(1) Active, stopped, then active again
(2) Active, then stopped

Durations of UNGFTN2 were 13-15 minutes throughout the July 4-7 observations, with no difference between May and July.

On July 7, Jet was inactive between 0540-0630, unmonitored from 0630-0720, and inactive between 0720-0744. The series of Jet eruptions between 0744 and 0837 contained seven periods, five of which were between 6-8 minutes, and two of which exceeded eight minutes. This period of inactivity combined with a short first series is indicative of the manner in which Jet behaved prior to eruptions of Fountain during July 21 through August 8, 1991, when Morning was not active. UNGFTN2 erupted at 0627 and 0842, a period of 2 hours 15 minutes.

JELLY:

Jelly's only known period of activity in the 1991 season was on May 5.

CLEPSYDRA:

Clepsydra stopped after each of the concerted eruptions of Fountain and Morning. On July 4, Dunns and Benders reported that "Approximately 10-15 minutes after the end of Fountain, Clepsydra shut off for 11 minutes." After the July 5 concerted eruption, Clepsydra stopped for seven minutes. This pause started nine minutes after Fountain ended.

The solo eruptions of Fountain on July 4 and July 6 also resulted in pauses in Clepsydra's activity. Two minutes after the 2226 July 4 solo eruption of Fountain ended, Clepsydra stopped for six minutes. After the 1322 July 6 solo eruption of Fountain, Clepsydra paused for four minutes. The pause started 11 minutes after Fountain ended.

SPASM:

Observations of Spasm's activity were not made with sufficient regularity to allow any discussion.

FOUNTAIN AND MORNING:

Activity of Fountain from May 26 through July 2: Data on Fountain extracted from the geyser log maintained at the Old Faithful Visitor Center for May 26 through July 2 showed 17 approximate periods for Fountain, ranging from 6 1/2 to 9 1/2 hours. (Only one closed period, 7 hours 18 minutes on June 18, was recorded. All other consecutive eruptions involved sightings in eruption and near start.) Six durations were recorded. Five of these were between 34 and 39 minutes. The one for 2131 eruption on July 2 (the only July 2 eruption listed) was shown as "> 40m".

Fountain's Activity on July 3: On July 3, eruptions for Fountain were recorded in the VC log for 0655 (period of 9 hours 24 minutes) and 1341ie (period of about 6 1/2 hours). Benders and Dunns reported: "On the evening of July 3rd, Fountain's pool partially filled during an observation period between 2000 and 2236. Data collection stopped at 2236, but other GOSA observers in the Kaleidoscope area did not witness an eruption of Fountain prior to their departure shortly after midnight."

The July 4 Concerted Eruption of Fountain and Morning: Dunns' and Benders' observations for July 4 were: "At 0915 we checked Fountain and found the pool level lower than at 2236 the night before with evidence that an eruption had occurred. The water level of the pool was just barely visible from the boardwalk. At 1030 the water level was higher, just beginning to surround but not cover the rocks at the back and bottom of the crater. We returned at 1230 to find the water still higher, covering most but not all the rocks at the back of the crater. However, the water had not risen high enough to begin going up the back ramp. We returned to Fountain at 1330 and remained throughout the day. From 1230 until the time of the eruption the pool level was relatively constant. Periodically, an increased amount of steam was emitted over Fountain's vent area."

"Fountain began [1440] its 4th of July eruption from a low pool. The eruption was initiated by rapid filling of the pool with water advancing up the back ramp that leads to the basin between Fountain and Morning. Violent boiling began immediately in Fountain and then it erupted. Prior to this action Morning's pool was about 6 to 8 inches from rim. Less than two minutes into the eruption of Fountain, water began to dome in the center of Morning's pool. The doming was rapidly followed by small [2-3 meter] eruptions. Morning soon began to erupt to much greater heights. The simultaneous play of these two geysers continued for 31 minutes until 1513 when Morning stopped. Fountain continued to erupt for a total of 95 minutes until 1615."

"Many of the bursts from Fountain reached heights which appeared greater than its normal 10-15 meter bursts. Often they exceeded those of Morning. However, at least 10 times, the Morning eruptions were much higher (over 30 meters) and appeared to contain a much greater volume of water than Fountain. When these massive eruptions hit the sinter, they produced waves which could be seen splashing up against Morning's old "beach" formations which lie about 9 to 10 meters from the crater. These larger eruptions resembled old photos of Excelsior's eruptions but on a smaller scale. Fountain erupted continuously without pause, whereas Morning's eruptions came in groups of bursts gradually increasing in height, with each of these groups separated by quiescent periods. One of Fountain's bursts drenched the onlookers on the boardwalk but no one seemed to mind on this warm 4th of July afternoon. On many occasions, the two geysers erupted simultaneously to significant heights."

Solo Eruption of Fountain on July 4: Fountain erupted next on July 4 at 2226, a period of 7 hours 46 minutes. Darkness precluded any determination of the strength of the 2226 eruption relative to other eruptions. The duration of this eruption was 50 minutes.

<u>Concerted Eruption Of Fountain And Morning On July 5</u>: Markers were not placed on Fountain following the 2226 July 4 eruption. However, available evidence indicated that Fountain probably did not erupt again until the concerted eruption of Fountain and Morning that started at 1343 on July 5, a period of 15 hours 17 minutes for Fountain. The water level in Fountain when it was first visited at 0600 on July 6, the lack of water on the sinter surrounding Fountain, the cold temperature of what little water there was around Fountain, and activity by Jet were not consistent with Fountain having had an eruption overnight.

Again, both Fountain and Morning were below overflow when the concerted eruption started on July 5. Using rocks at the western edge of Morning's crater as indicators, the water level immediately prior to the July 5 eruption was slightly higher than that from which it erupted in May. Boiling over Morning's vent on the north side of the pool and convection on the pool were observed beginning about 0900. This activity appeared to increase in intensity and frequency about an hour before the concerted eruption.

Fountain initiated the concerted eruption at 1343 (duration 82 minutes). Morning followed at 1345 (duration 21 minutes). Benders noted: "The characteristics of the July 5th concerted eruption were very similar to those of the July 4th eruption. However, we felt that the July 5th eruption was somewhat weaker than that on July 4th. The bursts of Fountain and Morning were not as numerous and powerful as those on July 4th and the durations of Fountain and Morning were shorter [95 vs 82 minutes for Fountain and 31 vs 21 minutes for Morning]."

Morning's eruption was again preceded by a sudden surge in water level, similar to what happened prior to the May eruptions. However, the start of the eruption was much slower and less crisp than the May eruptions. Morning seemed to struggle to erupt. Large waves rolled across the pool for almost a minutes, sending water toward Fountain, before the first small burst occurred. The character of the July 5 eruption also seemed different from that of the May eruptions. During the May eruptions, bursting was much more continuous than during the July eruption with fewer and shorter pauses between bursts. At times several seconds separated bursts during the July 5 eruption.

<u>Activity of Fountain on July 6 and 7</u>: Through the use of markers, it was determined that the next eruption of Fountain did not occur until 1322 on July 6, a period of 23 hours 39 minutes. Morning tried for another concerted eruption, but was unable to do so (until August 9). Boiling over Morning's vent and convection on the pool were noted starting about 9 am. Using rocks at the western edge of the pool as indicators, the water level, although still below overflow, was higher on July 6 than it was on July 5 when Fountain started. Morning surged and sent large waves rolling across its pool just after the start of Fountain.

Fountain erupted again on July 6 at 2156, a period of 8 hours 34 minutes. Through the use of markers, it was determined that Fountain erupted sometime in the early morning hours of July 7, and then was seen near start at 1050 on July 7, for an average of 6 hours 25 minutes for the two periods.

CONCLUSION:

The concerted eruption of Fountain and Morning that occurred on August 17-18, 1959, was clearly stimulated by the Hebgen Lake earthquake. Were these July concerted eruptions stimulated by earthquake activity, and what about the activity of Morning in May 1991, and subsequently, what about the concerted eruptions that occurred on August 9, 28, and 29, 1991? The answer is, apparently not. NPS personnel were questioned and there were no reports of unusual earthquake activity or swarms of small earthquakes during these times.

A draft of this report distributed in July 1991, concluded with the statement: "I'll be spending some time in the Lower Geyser Basin in August collecting data [to determine 1991 eruptive patterns of features in the Fountain Complex], hoping to get lucky and see a third eruptive episode of Morning." I did spend time there and I did get lucky a third time with Morning. But those are subjects for other reports.

ACKNOWLEDGMENTS:

I would like to thank all the geyser gazers who shared the hot, unshaded hours during which these observations were made. I would particularly like to thank the Dunns and Benders for permission to use information from their unpublished report "Fountain And Morning Eruption, July 4, 1991", Doug Colin and Rocco Paperiello for providing July information, Ann Deutch who kept me company while I was waiting for Fountain's eruption to end during the late evening hours of July 4, Mike Keller for providing May information, and Jens Day who provided May information and whose company enabled me to see the 0025 May 5 eruption of Morning since I probably would not have stayed out alone.

FOUNTAIN COMPLEX, July 4-7, 1991

Fountain Complex, July 4, 1991

Jet	Period	UNGFTN2	Twig's Sat.	Others
1738 (last Jet until Fountain erupted)				
			1806, d = 3m	
		1908, P = 3 hr 38 m		
			2018	
		2058, P = 1 hr 58m		
				2226, Fountain P = 7h46m, d=50m Clepsydra stop 2318-2324
		2233ns, P = app. 1 hr 35m		

Jet approximately every two minutes during Fountain's eruption

Fountain Complex, July 5, 1991

Jet	Period	UNGFTN2	Twig's Sat.	Others
0619				
0625	6m			
0632	7m			
0639	7m			
0647.02	8m			
0653.57	6m 55s			
0701.55	7m 58s			
0709.24	7m 29s			
0716.17	6m 53s			
0722.56	6m 39s			
0729.27	6m 31s			
0736.09	6m 42s			
0743.45	7m 36s			
0750.00	6m 15s		0754, d = 2m	
0756.30	6m 30s			
0804.15	7m 45s			
0811.40	7m 25s			
0819.50	8m 10s			
0827.45	7m 55s			
		0834, d = 13m		
			0840.45, d = 2.5m, P = 46m	
0906	39m			
0913.29	7m			
0919.55	6m 26s			
0926.25	6m 30s		0931, d = 2m, P = 51m	
0933.50	7m 25s			
0940.50	7m			
0948.53	8m 3s			
0955.15	6m 22s			
1002.50	7m 35s			

Fountain Complex, July 5, 1991 (continued)

Jet	Period	UNGFTN2	Twig's Sat.	Other
			1005, d = 4m, P = 34m	
1010.11	7m 21s		1016, d = 4m, P = 11m	
1017.45	7m 20s			
1025.05	7m 20s			
1032	7m			
1039	7m			
1045	6m			
1054	9m			
1100.25	6m			
1109.20	8m 55s			
		1115, P = 2hr 41m		
			1127, d = 2m	
1147	38m			
1155	7m			
1202.40	7m			
1209.50	7m 10s			
1216	6m			
1222	6m			
1233	11m			
1241	8m			
1248	7m			
1255.30	7m			
1302.58	7m 28s			
1309.12	6m 14s			
1315.05	5m 53s			
1322.10	7m 5s			
1329.25	7m 15s		1331	
1336.32	7m 7s			
1342.27	5m 55s			
				1343 FOUNTAIN P = 15hr17m, d = 1hr21m Clep. stop 1513-1520
				1345 MORNING P = 23hr3m, d = 21m
		1345ns, P = app. 2 h4 30m		
1346	4m			

Jet erupted about every two minutes during Fountain's eruption

------------------Break in data------------------

Jet	Period	UNGFTN2	Twig's Sat.	Other
			1930, d = 3m	
			1948, d = 2m, P = 19m	
		2031, d = 13m		
		2218, d = 12m, P = 1 hr 47m		
2311	> 3 hr 46m			
2318.45	7m 45s			
2325.45	7m			
2334	8m			
2340.10	6m			
2346.33	6m 23s			

Fountain Complex, July 6, 1991

Jet	Period	UNGFTN2	Twig's Sat.	Other
0339.30				
0346.30	7m			
0353.20	6m 50s			
0401.25	8m 5s		0404, d = 2.5m	
		0408, d = 13m		
			0430, d = 2m, P = 26m	
0436.20	35m			
0443.55	7m 35s			
0451.55	8m			
0459.05	7m 50s		0500, d unk., P = 30m	
0506.05	7m			
0512.40	6m 35s			
0519.43	7m 3s			
0526.18	6m 35s		0529, d = 3m, P = 29m	
0532.47	6m 29s			
0540.54	8m 7s			
0548.24	7m 30s			
0556.36	8m 12s		0557, P = 28m	
0603.36	7m			
0611.17	7m 41s			
0618.30	7m 13s			
0625.27	6m 53s		0626.30, d = 5m, P = 29m	
0634.26	8m 59s			
0641.02	6m 36s			
0649.07	8m 5s		0652.50, d = 4m, P = 26m	
0658.08	9m 1s			
0706.18	8m 10s			
		0710.30, d = 14m, P = 3hr 2m		
			0720.15, d = 4m, P = 27m	
0743.28	37m		0747, P = 27m	
0750.24	6m 56s			
0758.58	8m 34s			
0807.30	8m 32s			
0816.00	8m 30s		0817, P = 30m	
0823.50	7m 50s			
0830.30	6m 40s			
0838.30	8m			
0846.57	8m 27s			
0855.07	8m 10s			
0904.05	9m 43s			
0913.38	8m 48s		0914	
0923.20	9m 42s			0918 Twig, d = 3h4 32m
0931	8m			First Twig since Twig was
0939.15	8m			marked at 0615 on July 5
0949.14	9m 59s			
0958.38	9m 23s			
1007.44	9m 6s			
1017.26	9m 42s			
		1022, d = 13m, P = 3hr 12m		

Fountain Complex, July 6, 1991 (continued)

Jet	Period	UNGFTN2	Twig's. Sat.	Other
1054.30	37m			
1101.35	7m 5s			
1109.27	7m 52s			
1119.24	9m 57s			
1128.30	9m 6s			
1136.11	7m 41s			
1145.06	8m 55s		1152	
1159.53	14m 47s			
1208.08	8m 15s			
1215.59	7m 51s			
1223.55	7m 56s			
1232.22	8m 27s			
1241.53	9m 31s			
1251.40	9m 47s			
1302.20	10m 40s		1306	
		1306, d = 15m, P = 2 hr 44m		
				1322, FOUNTAIN P = 23hr 39m, d = 40m
1330.24				Clepsydra stop 1417-1421

Jet every 1-2 minutes during Fountain

-------------------------break in data-----------------------

2156 FOUNTAIN, P = 8hr34m

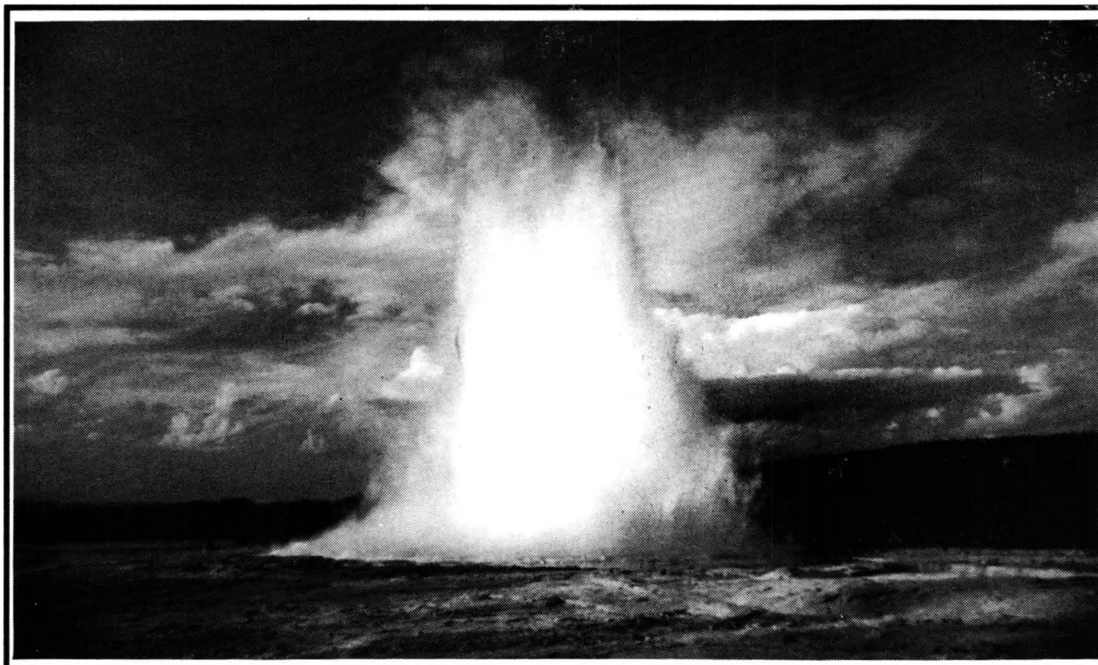
Fountain Complex, July 7, 1991

Jet	Period	UNGFTN2	Twig's Sat.	Other
		0627		
			0731, d = 3.5m	
0744.16				
0751.40	7m 24s			
0758.30	6m 50s			
0806.50	8m 20s			
0813.46	6m 56s		0816, P = 45m	
0822.24	8m 40s			
0830.08	7m 44s			
0837.50	7m 42s			
		0842, P = 2 hr 15m, d = 17m		
			0855, P = 39m	
0922.40	45m		0928, P = 33m	
0931.30	8m 50s			

-------------------------break in data-------------------------

1050 ns FOUNTAIN,
approximately 12 hours 50 minutes for two eruptions for a 6 hr 25m average

The second of the two concerted eruptions of **Morning Geyser** (left) and **Fountain Geyser** that took place in early July, 1991. Photo by Lynn Stephens



One of the eruptions of **Morning Geyser** during the short–interval series of August, 1991. Photo by Lynn Stephens

A bursting "blue bubble" during the August series of eruptions by **Morning Geyser**. Photo by Lynn Stephens

Morning Geyser (right) and **Fountain Geyser** in concert on August 29, 1991, during what turned out to be the final eruption of the 1991 active episode. Photo by Lynn Stephens

1991 ACTIVITY OF MORNING GEYSER AND OTHER FEATURES IN THE FOUNTAIN COMPLEX PART III, August 9-29, 1991

by Lynn Stephens

ABSTRACT: The activity of Morning on May 4 and 5 and July 4 and 5, 1991, (discussed in separate reports) was just a prelude to its activity in August 1991, when Morning had three concerted eruptions with Fountain and 118 verifiable solo eruptions. This report summarizes Morning's activity during the period August 9-29, 1991, and the impact Morning had on other geysers in the Fountain Complex.

INTRODUCTION

1991 was a record-breaking year for Morning Geyser. First, there was the excitement on May 4 and 5 when it was discovered that it had emerged, albeit briefly, from an eight-year period of dormancy that started after an eruption on February 10, 1983. Then there were the unprecedented non-earthquake induced concerted eruptions of Morning and Fountain on July 4 and 5. But Morning waited until August to put on its main show.

Morning's activity in August started with a concerted eruption with Fountain on August 9 and ended with two more concerted eruptions, one on August 28 and one on August 29. Between those concerted eruptions there were 94 solo eruptions witnessed by GOSA observers, 17 eruptions recorded by a portacorder, 5 eruptions verified through the use of markers, and 2 eruptions inferred using the average period--for a total of 118 verifiable eruptions. Starting with the first observed solo eruption on August 10 and ending with the last solo eruption on August 28, for 18 days Morning erupted on the average every 3 hours 45 minutes with a standard deviation of 21 minutes.

The first section of this report discusses the activity of Morning Geyser for the period August 9-29, 1991. The second section discusses the impact that Morning's rejuvenation had on other geysers in the Fountain Complex. Appendix A contains a complete list of the 1991 eruptions of Morning Geyser.

MORNING GEYSER

This section of the paper begins with a brief history of Morning's activity prior to 1991. This is followed by sections discussing (1) the August 9 concerted eruption with Fountain, (2) the solo eruptions of Morning from August 10 through August 28, and (3) the concerted eruptions with Fountain on August 28 and 29.

Brief History of Activity by Morning Geyser: Although the crater of Morning Geyser was described by Peale [1878] in Hayden's [1883] report, Morning Geyser was not known to be an eruptive feature until 1899. A newspaper clipping dated June 27 [reproduced in *Yellowstone Nature Notes*, 1956, p. 19] stated: "At 9:20 yesterday [June 26] morning and continuing until 10:25 without intermission there was an eruption from a crater about fifty feet north of the Fountain Geyser, which we have always considered to be nothing more than a pool having no name...I do not exaggerate when I say the height it played was from 200 to 250 feet, and was the grandest I have ever witnessed in the park." The next reported activity for Morning was during the 1909 season [Haynes, 1912]. From then until the mid 1940's, the only located reports of activity are for one in August of 1921 [*Monthly Report of the Superintendent*, August 1921] and one on July 4, 1922 [*Monthly Report of the Superintendent*, July 1922].[1]

Marler [1973] indicates activity of Morning Geyser from the mid-1940's through 1959 as follows: 1944--one eruption; 1945--one eruption; 1946--two eruptions; 1947--at least one eruption occurred over the winter and 11 eruptions were recorded from June 11 through September 22; 1948--36 eruptions; 1949--11 eruptions; 1950 and 1951--dormant; 1952--one eruption in April and from July to the beginning of September there were 2 to 3 eruptions per week; 1953--2 to 3 eruptions per week; 1954--Morning was active from June through August; 1955--22 eruptions; 1956--34 eruptions; 1957--50 eruptions; 1958--54 eruptions. Prior to the 1959 earthquake, there were only 14 recorded eruptions in 1959. Morning and Fountain had a concerted eruption beginning at 11:37 PM on August 17, 1959, which was still going on the morning of August 18 when Marler arrived at the Lower Geyser Basin. From then until September 1, Morning continued to have periodic eruptions. By September 1 durations of Morning's eruptions were 3 to 5 minutes, with pauses between eruptions lasting 60 to 73 minutes, and the magnitude of the eruptions was only about 10 feet [Marler, 1964].

Following cessation of its activity after the 1959 earthquake, Morning was inactive until 1973, when 18 reported eruptions have been located [Koenig, "Data Logs", plus one additional one on May 24 located by Rocco Paperiello].[2] Morning was then dormant until 1978, active in 1978, and

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[1]See Whittlesey [1988] for an explanation of why the 1923 eruption reported by Marler actually refers to a 1921 eruption.

[2]Note that activity in 1974 by Morning Geyser listed in Bryan (1991) and Whittlesey (1988) appear to be typographical errors meant to refer to 1973 activity since no records of activity in 1974 have been located.

dormant again in 1979 and 1980. In 1981, 82 eruptions of Morning are listed in the geyser logs maintained at the Old Faithful Visitor's Center (OFVC). Prior to 1991, this was the most eruptions of Morning recorded in a single year. Morning was again active in 1982, with 44 eruptions listed in the OFVC geyser log. One eruption in 1983 on February 10 is listed in the OFVC geyser log, with the notation "probable delayed response to tremors on Sunday 02/06/83".

The 118 verifiable solo eruptions of Morning in August alone would have made 1991 the year with the most recorded activity. Add the five observed solo eruptions in May, the two concerted eruptions with Fountain in July, and three more concerted eruptions with Fountain in August, and 1991 known eruptions of Morning total 128, a 56% increase over the previously reported record number of eruptions (82) for a single year (1981).[3]

One reason for the record number of reported eruptions is that a determined effort by human observers to record as many eruptions as possible during August was supplemented by the use of a portacorder to record eruptions overnight. The list of 1991 eruptions of Morning Geyser (Appendix A) is almost a complete record of its 1991 activity, with the exception of eruptions prior to the 0938 May 4 eruption that were missed, and one or possibly two eruptions that may have been missed overnight on August 9-10.

A more significant reason for the record number of reported eruptions is the fact that Morning was erupting from a non-overflowing pool at an average period of 3 hours 45 minutes for three weeks. Marler [1973] noted that Morning sometimes erupted from a low pool during the 1957 season. Lewis [1957, pp. 53-54] noted that "At least four times this summer Morning has erupted twice in the same day. At least three of these eruptions were from a partially filled crater. Although I did not see them, they were reported by reliable sources including Park Rangers William Baker, Riley McClelland, Billy J. Hall and Kenneth Fink. According to Park Naturalist George Marler, this has not happened before. During the time Morning refills, it often boils considerably. It was during these boiling periods that Morning erupted before being completely filled." For 1957, Marler [1973] also reported that there was a 12 hour period for Morning on

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[3]The known total should probably be stated as exceeding 128 since R. Hutchinson, Park Geologist, indicated that the 0938ie May 4 eruption of Morning was not the first eruption in that series based on his observations of the clarity of the water. Also, it is possible that one or two eruptions of Morning were missed between the 8/9 concerted eruption with Fountain and the first observed solo eruption of Morning at 0516 on 8/10 since a marker was not placed on Morning overnight.

September 5, 1957, three eruptions in a 25 hour period on September 16-17, and a 3 hour 20 minute period on September 19. Marler reported that activity in 1958 was "similar" to that in 1957, but did not elaborate on whether this included low pool and/or less than 4 hour periods. Neither of the reports even hint that consecutive less than 4 hour periods occurred for any extended period of time.

The Beginning--The Concerted Eruption of Morning and Fountain on August 9: Between July 22 and August 3, Fountain's periods were between 6.5 and 7.5 hours, with the exception of an 8 hour 44 minute period on July 28 and a period exceeding 16 hours on July 25-26. In July I had stated that I thought Fountain needed to "stall" (have a long period) for Morning to have a chance to erupt, even though the long period on July 25-26 had not resulted in an eruption of Morning. On August 4, Fountain's periods started to lengthen. Overnight on 8/3-8/4 a double period averaged 9 hours 20 minutes for two periods, and was followed by a 9 hour 15 minute period. The next double period overnight on 8/4-8/5 dropped back to the 1991 "normal", averaging 6 hours 41 minutes for two periods. This was followed by a 10 hour 1 minute period. But on 8/6 and 8/7 the next six periods were back to 1991 normal, averaging 7 hours 32 minutes. Overnight 8/7-8/8, the two period average was 9 hours 10 minutes, followed by an 8 hour 15 minute period. Overnight 8/8-8/9 the two period average was 7 hours 15 minutes.

Hindsight showed that I was correct that Fountain needed to stall (at least a little) and that Fountain's activity had become erratic six days prior to the August 9 concerted eruption with Morning. But at the time I wasn't really expecting Morning to reactivate and was more concerned that I was having a difficult time getting Fountain starts when I had skipped an overnight eruption.

Fountain erupted at 1004 on August 9, duration 41 minutes. I arrived back at the Fountain Complex at 1624, anticipating the next Fountain eruption somewhere between 1630 and 1730 based on a 6.5 to 7.5 hour period. Spasm was in eruption at 1624 and stopped at 1736. Jet was in an eruptive cycle, with periods in the 4 to 6 minute range, short enough to indicate Fountain was close, and, indeed, slightly shorter than expected. UNGFTN2 erupted at 1815, and Jet was quiet for 37 minutes. When Jet resumed activity, periods were in the 5-6 minute range. Fountain's water level was slowly creeping upward, but was not going out the "ramp" toward overflow. Fountain's period stretched out to 9 hours 19 minutes (a slight stall). Fountain started erupting at 1923. Morning's water level immediately began to rise and boil, and Morning started bursting at 1924.

Morning erupted for 38.5 minutes, stopping at 2002.34. Bursts were sometimes separated by several seconds. I did not note that the water seemed cloudy or milky, but the backlighting and my excitement could have prevented me from noting that. After Morning stopped, it drained while Fountain was still erupting. When Fountain erupted solo, Morning had stayed full during Fountain's eruption.

Fountain stopped at 2125, a duration of 2 hours 2 minutes. Fountain's eruption seemed to be much more powerful (in terms of the height of the bursts) than when Fountain had been erupting solo in July and early August, despite the fact that some of the July/August eruptions had occasional bursts that were estimated to be 25 meters. In my opinion, the August 9 concerted eruption was more powerful than the July 5 concerted eruption had been, but that may have been because the eruption of Morning lasted almost twice as long and the eruption of Fountain lasted 40 minutes longer than on July 5.

Clepsydra's roaring from steam phase activity was noted at 1944, and was noted still roaring at 2024. Clepsydra stopped after Fountain's eruption. The pause started at 2133.37 (8 minutes after Fountain ended) and ended at 2137, a duration of approximately 3.5 minutes.

Spasm was not in eruption when Fountain erupted, and had not started when I left at 2137. At 2110, I noted that Jelly was totally empty. Twig had been splashing in the vent since 1641 and erupted at 2001. Twig was still in eruption at 2137. Periods for Twig's Satellite Vents were 13.5 to 14.5 minutes for the three hours preceding the concerted eruption. Jet erupted at 1.5 to 2.5 minute periods during the concerted eruption. Jet stopped at 2124 and had not resumed activity at 2137. UNGFTN2 erupted at 2006, period of 1 hour 50 minutes, duration 16 minutes, and again at 2124, period of 1 hour 18 minutes.

After Fountain stopped, a marker was placed on it, but no marker was placed on Morning that night.

The Middle--Solo Eruptions of Morning from August 10-August 28: When I arrived at the Fountain Complex at 0500 on August 10, I noted that the marker on Fountain was in place and Fountain's water level had not come out of the inner crater. Jet and Twig were quiet, and Jelly was down about 25 centimeters below ground level. As a marker was being placed on Morning, I noted that the water level was above the platform rock that we had been using as an indication of the water level on May 4 and 5, that there were convection currents on the surface of Morning's pool, and that there was no water in the area surrounding Morning's crater. Within minutes that changed, as Morning erupted at 0516. The eruption lasted 10 minutes. At 0545, as I placed another marker on Morning, I noted that Clepsydra had continued after Morning stopped, and Spasm had also continued. UNGFTN2 had started sometime between 0516 and 0522 and stopped at 0534. Jelly's water level had stayed stable. Morning's water level had dropped about 2/3 meter below ground level.

That eruption was the first of the 118 verified solo eruptions of Morning between August 10 and August 28. The eruptions occurred at an average period of 3 hours 45 minutes, with a standard deviation of 21 minutes. The shortest recorded period was 3 hours 10 minutes, and the longest recorded period was 5 hours 3 minutes (the only period exceeding 5 hours). Durations were determined for 108 eruptions. The average was 21 minutes, with a standard deviation of 5 minutes. Durations ranged from a low of 10 minutes to a high of 31 minutes 57 seconds. Analysis showed no significant correlation (even with 100 degrees of freedom) between durations and either the preceding (r^2=.10) or the succeeding (r^2=.03) period.

Long periods seemed to be correlated with wind conditions.[4] Marler [1973] had stated that windy conditions delayed eruptions of Morning, but I had interpreted his statement to apply to Morning when it was erupting from an overflowing crater. I had noticed that long periods tended to occur in the afternoon. I had also noticed that when I missed one eruption overnight I needed to arrive before the 6.5 hour mark to ensure that I did not miss the next eruption. Or, as several observers learned to their dismay, projecting ahead three eruptions from a late evening eruption to a morning eruption using the 3.75 hour average meant arriving too late for the morning eruption.

I did not make the connection with wind until Tim Thompson, summer research assistant to R. Hutchinson, commented one afternoon that I should note that the conditions were windy. Windy conditions usually occur at the Fountain Complex in the afternoon; the most likely period of calm is overnight. Longer than average periods occurred in the afternoon; shorter than average periods occurred at night. I have no explanation why wind delayed eruptions of Morning when it was erupting from a partially filled crater--just the observation that this is what the data indicates.

All the observed eruptions started from a partially filled crater. Although measurements could not be taken, rocks in the crater were used to determine that the level from which Morning started its eruption did vary. There appeared to be a certain necessary minimum water level, but once the water reached that level, the longer the period, the higher the water crept. Convection currents on the surface of the pool were visible from the Fountain overlook. Air bubbles could be seen breaking the surface. Then, suddenly, the water would

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[4]It is possible that this wind effect masked correlation between durations and periods. Data collection techniques were not sufficient to allow testing of this hypothesis.

surge and surface boiling would start. The boiling would increase, a small burst would occur, and then the eruption would start. Although I witnessed over 80 eruptions, I never saw any activity that I would equate with the 1957 activity that Lewis [1957] described, where he indicated that during the time Morning refilled "it often boils considerably. It was during these boiling periods that Morning erupted before being completely filled." In 1991, considerable boiling invariably resulted in an eruption.[5]

Observers who had witnessed Morning's activity in 1982 and saw it again in 1991 agreed that the 1991 eruptions were less impressive because the height of the bursts was less, the bursts were separated by more time, there were none of the "Granding" type bursts where the entire column of water lifted in a manner similar to Grand's eruption, and the durations were much shorter in 1991 than they had been in 1982. However, the 1991 eruptions of Morning were still a magnificent sight.

During the first few days of Morning's activity, Mary Beth Schwarz and Ralph Taylor triangulated maximum heights, using inclinometers and the base line at the foot of the stairs. The maximum heights they obtained were 35-40 meters. (Observations were recorded in the OFVC logbook.)

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[5]This could be a matter of how "boils considerably" is interpreted. To me, boils considerably indicates activity where the surface is agitated to the point of white froth being visible on the blue surface of Morning's pool. This condition only occurred at the start of an eruption. Also, Lewis uses the phrase "boiling periods"--note the use of the plural form for period. In 1991, Morning would only have one boiling period--the one that immediately preceded an eruption. There were no white froth type boiling periods that did not result in an eruption.

However, if "boils considerably" meant strings of bubbles rising to the surface without creating a froth, similar to the strings of bubbles that can be seen in Artemisia's pool for a long time preceding an eruption, then yes, Morning did "boil considerably" because this sort of bubbling could be seen from the Fountain overlook.

Although an eruption of Morning invariably followed the white froth type boiling in August 1991, start times were recorded at the time of the first bursting activity because surface boiling was not visible for eruptions that occurred after dark, bursting was the point of certainty that an eruption had started, that was the method used for the first few eruptions, and the method yielded results consistent with start times recorded on the portacorder where duplicate observations were available. This method was approved by R. Hutchinson, Park Geologist.

Later in August, I observed a few bursts that were judged to be 40-45 meters (based on relationship of the maximum water height to the horizon compared to measured heights and their relationship with the horizon), but there were very few of these bursts.

Just as impressive as the height of the bursts was the width and nature of the bursts. Some bursts sent a jet of water straight up--what John Muller termed a "bullseye". Other bursts would go out low and wide to the northeast, sending a solid stream of water to the edge of the berm, 20 meters out. A few bursts went to the southwest, landing in Fountain's crater. Big bursts were scattered throughout the duration of each eruption, with big bursts just as likely in the middle and at the end of the eruption as they were at the beginning of the eruption. In fact, Morning often seemed to save its best efforts for the final few minutes of the eruption.

But most impressive of all were the blue bubbles--not just the possibility of one at the beginning of the eruption like Great Fountain has, but blue bubbles throughout the eruption. The surface level of the pool would calm, and the water would seem to settle slightly. Then the surface level would lift evenly, like a blue plate. As it reached the top of the crater, it would dome, and, if the observer were lucky, a large mass of blue water would rise above the crater before fracturing into a blue spider web. Sometimes the mass of blue water rose to a height of 3-5 meters (measured from photographs). At other times the surface of the water would break and a burst occur before a blue bubble could develop. Although the process only took a few seconds, there was sufficient time for a feeling of anticipation to develop when the surface calmed--would it result in a little bubble, a little burst, a big burst, or best of all, a big bubble?

The end of an eruption always seemed to come as a surprise. One of the times that the surface calmed, the water level would start to recede instead of lift. Then boiling would resume as the water level continued to recede. Because big bursts were just as likely to occur near the end of the eruption as they were to occur at the beginning, there was never any sense that Morning was winding down an eruption; rather, there was the feeling that the eruption had ended with no warning.

The end of Morning's solo eruptions in 1991 also came as a surprise to me, although not to Ralph Friz. The final solo eruption of Morning in 1991 occurred at 1138 on August 28. It was preceded by a 3 hour 53 minute period and the duration was 11 minutes 30 seconds. Ralph Friz commented that the eruption was both very short in duration and very weak, with fewer tall bursts and blue bubbles, and more time between bursts than had been the case with prior eruptions he had seen. Since there had been other Morning eruptions with durations in the 10 to 13 minute range, I did not believe that the short duration itself indicated the demise of Morning. Since short durations meant less time for tall bursts and blue bubbles, I was not overly concerned about the nature of the eruption. Examination of data on eruptive patterns of other features in the Fountain Complex showed nothing out of the ordinary. However, Ralph Friz was correct--this was the last solo eruption of Morning for 1991.

The End--Concerted Eruptions of Morning and Fountain on August 28 and 29: On the afternoon of August 28, data collection in the Fountain Complex resumed at 1414. Ralph Friz and I were waiting for the next eruption of Morning. As the period stretched beyond the five hour mark, we began to get concerned despite the fact that Jet and UNGFTN2 were still exhibiting Morning mode activity instead of Fountain mode activity, with Jet erupting during an eruption of UNGFTN2. (See the next section of this paper for discussion of the different types of activity.) At 1700, the water level in Fountain was not visible from the boardwalk. The water level in Morning had risen to the maximum level from which it had been erupting, although it was still well below overflow. At 1745 the water level in Fountain was visible from the boardwalk.

At 1745 I left the Fountain Complex to return to the Upper Geyser Basin to notify NPS personnel that I might be at Fountain Complex all night, to get supplies necessary for an all-night, cold weather vigil, and to inform other GOSA observers that Morning had "stalled". Ralph Friz remained at the Complex, intending to go to the Upper Basin to get supplies after I returned.

I returned to the Lower Geyser Basin, and as I was leaving the parking lot, headed toward Morning, I saw a large steam cloud lifting from the Morning/Fountain area at 1853--a steam cloud that was from a concerted eruption of Morning and Fountain.

Ralph Friz reported that while I was gone, the water level in Fountain continued to creep up, but neither Fountain nor Morning had reached overflow. Fountain started the concerted eruption at 1853, and Morning followed, still at 1853. The start was similar to the start of the concerted eruption on July 5.

This eruption was more powerful than the July 5 concerted eruption.[6] Fountain was throwing muddy water and rocks. The water cleared during the first 20 minutes of the eruption, although Fountain continued to throw rocks out throughout most of the

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[6]In fact, in my subjective opinion, it was the most powerful of the four concerted eruptions--7/5, 8/9, 8/28, and 8/29--that I witnessed. Ralph Friz, Herb Simons, and Doug Colin agreed that it was the most powerful of the three--7/5, 8/28, and 8/29--that they witnessed.

eruption. Many bursts from Fountain were estimated to be 30 meters high. Often, large bursts from Fountain and Morning seemed to alternate, although sometimes both would have simultaneous bursts.

Morning's eruption ended at 1929, a duration of 36 minutes. Fountain's eruption continued until 2113, a duration of 2 hours 20 minutes.

Clepsydra was noted to be in steam phase at 1908. Clepsydra stopped from 2120.30 to 2126.15, a pause of 4 minutes 45 seconds. The pause started seven minutes after Fountain stopped. Twig was noted in eruption at 1908. Spasm was not in eruption when Fountain and Morning started. (Spasm had ended an eruption at 1720.) Jet erupted about every 1.5 to 3 minutes during Fountain's eruption. UNGFTN2 erupted from 1954 to 2011, a duration of 17 minutes, and was noted in eruption again at 2114, a period of approximately 1 hour 20 minutes. The behavior of these geysers was quite similar to behavior that had been observed with the July 5 and August 9 concerted eruptions of Morning and Fountain.

The Fountain Complex was under continuous observation until the next concerted eruption of Morning and Fountain at 1214 on August 29, except for rest breaks taken in the parking lot. This time there was no solo activity from either Fountain or Morning between the two concerted eruptions, unlike July 4 and 5 when there was a solo eruption of Fountain between the two concerted eruptions.

The eruption of Twig that was noted at 1908 on 8/28 ended sometime between 2130 and 2150. Twig next erupted at 1259 on 8/29, a period of approximately 18 hours. This eruption lasted 1 hour 4 minutes--a very short duration compared to the in excess of 4 hour durations that were observed in late July and in August. Spasm remained off until sometime between 0600 and 0643 on 8/29, a period exceeding 12 hours. But the next period for Spasm was back to "normal" when Spasm erupted again at 1005.

After the 8/28 Fountain portion of the concerted eruption ended, Jet continued to erupt. Between 2150 and 2225, periods were in the 2 to 3 minute range. For the next hour, periods increased to the 4 minute range. Jet stopped erupting sometime between 2344 8/28 and 0003 8/29. Jet remained quiet until 0933 on 8/29, a period of approximately 9.5 hours. Between the end of the 8/28 Fountain portion of the concerted eruption and the concerted eruption at 1214 on 8/29, UNGFTN2 erupted at 1.75 to 2 hour periods, with most durations in the 12-14 minute range.

At 1000 8/29, Fountain's water level was still in the inner crater. Fountain started rising quickly at 1105, but had not reached overflow when it erupted at 1214.10, a period of 17 hours 21 minutes. The eruption lasted 1 hour 38 minutes, and appeared comparable to the July 5 concerted eruption with Morning. Although it was less powerful than the August 28 concerted eruption, it was still more powerful than solo eruptions of Fountain in July had been. There were rocks thrown out during the eruption although the water was not muddy. Clepsydra stopped from 1358.35 to 1403.35, a pause of 5 minutes that started six minutes after Fountain ended.

Water was visible in Morning's crater at 0845. At 1055 Morning started having periodic strings of bubbles that caused convection waves on the surface. At 1142 it was noted that convection currents on the surface of the pool made Morning appear to be pulsing. When Fountain started at 1214, Morning's water level had not reached overflow stage. After Fountain started, Morning rose quickly and boiled. Morning started erupting at 1215, 1 minute 15 seconds after the start of Fountain's eruption. Morning erupted from 1215.25 to 1242.50, a duration of 27 minutes 25 seconds, and a period of 17 hours 22 minutes.

This concerted eruption was Morning's last activity for 1991. Fountain erupted at 2101 on August 29, a period of 8 hours 47 minutes. Jet had stopped erupting sometime between 1404 and 1635, and did not resume eruptions prior to the Fountain eruption. It was reported to me that Morning made no attempt to erupt at the start of this eruption of Fountain, and Clepsydra was "dead" during Fountain's eruption. Eruptions of Fountain were observed at 0801 and 1640 on August 30. Just after the 1640 eruption of Fountain started, Morning's satellite vent bubbled and overflowed into Morning--the first time this had been noted in July or August. We had been told that activity from the satellite vent indicated Morning had returned to dormancy during the 1981 and 1982 activity, and this was true again in 1991.

The shift in energy away from Morning was confirmed by the portacorder. Examination of the portacorder strip for August 28 showed that "noise" representing steam bubbles collapsing underground in Morning's system had started at roughly 1500, the 4 hour mark when we were expecting the next solo eruption of Morning, and continued until the concerted eruption started at 1853. The portacorder was removed on the morning of August 29 so that the batteries could be recharged, and replaced at about 2030 that evening. Examination of the portacorder strip for overnight 8/29 and during the day 8/30 showed that the "noise" had disappeared, indicating the energy had shifted away from Morning.

As of early April, 1992, no further activity from Morning Geyser has been observed. Markers placed on Morning Geyser remained in place through the winter season. When I visited the area in December, 1991, there was snow right up to the edge of Morning's crater.

The next section of this paper discusses how the activity patterns of UNGFTN2 and Jet, Clepsydra, and Spasm were affected by the shift in energy in the Fountain Complex from Fountain to Morning.

IMPACT OF MORNING GEYSER ON OTHER GEYSERS IN THE FOUNTAIN COMPLEX

Extensive observations of the Fountain Complex were made during the period July 22 through August 8, 1991, when Fountain was active but Morning was not. This section of the paper describes[7] the eruptive patterns exhibited by Jet, UNGFTN2, Spasm, and Clepsydra during the period Fountain was active, and compares this activity with activity in August when Morning was active.

Descriptive Cycle of Activity in the Fountain Complex July 22-August 8, 1991: During the 1991 season, Fountain was generally erupting at 6.5 to 7.5 hour periods, with most durations lasting 40 minutes. Fountain was erupting from a "low" pool, was not seen in overflow during 1991, and would sometimes erupt when the water level appeared to be half a meter below the top of the crater. Often, experienced observers, upon arriving for their first look at Fountain in 1991, would ask for the next prediction for Fountain, look at the water level, say "No way!" or "Are you sure?", and then be surprised when Fountain erupted within the prediction window and at how low the water level was when Fountain did erupt.

Observations of several cycles between Fountain eruptions revealed the following general pattern of activity in the Fountain Complex. Following an eruption of Fountain, Jet would cease activity for a period of time, then resume activity anywhere from 1.5 hours to not at all before the next eruption of Fountain. Jet's periods between eruptions would start at approximately 10 minutes and gradually shorten to approximately 6 minutes before Fountain erupted. During Fountain's eruption, Jet would erupt at 1.5 to 3 minute periods. UNGFTN2 would erupt at 2 to 2.5 hour periods, with durations lasting 13-16 minutes. Jet's last one or two periods before an eruption of either Fountain or UNGFTN2 would show a slight increase. If Fountain was not in eruption, Jet would cease activity during an eruption of UNGFTN2 and would remain quiet for 20 to 45 minutes. If UNGFTN2 erupted and Fountain started during Jet's quiet period, Jet would remain quiet for part of Fountain's eruption, before starting its 1.5 to 3 minute periods. But if Fountain started and then

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[7] Descriptions of the patterns of activity observed from July 22-August 8 are presented here, without any attempt to include detailed analysis, statistics, and exceptions to the general patterns that were observed. It is intended that a detailed analytic report, which will include Twig and Twig's Satellite Vents will be published in a future edition of *Transactions*.

UNGFTN2 erupted, the eruption of UNGFTN2 would not cause Jet's activity to cease.

Clepsydra was in constant activity except for pauses after Fountain's eruptions. Clepsydra paused after 55% of Fountain's eruptions. The pause usually occurred about 10 minutes after Fountain stopped, and would last for 3-4 minutes.

Spasm usually erupted once in each period between Fountain eruptions. Spasm's eruption would start 30-60 minutes before Fountain's eruption started. Runoff from Fountain would then flow into Spasm, ending Spasm's eruptions.

Once the energy in the Fountain Complex shifted from Fountain to Morning, these patterns showed significant changes.

Fountain: Fountain ceased activity between the concerted eruption with Morning on August 9 and the concerted eruption on August 28. The marker placed on Fountain after the August 9 eruption at 1923 ended remained in place until the August 28 eruption at 1853, a period of 18 days 23 hours and 30 minutes. The sinter around Fountain turned white.

Each eruption of Morning sent a flood of water pouring into Fountain and pushed many pieces of loose sinter into Fountain's crater. Although the flood at times appeared to be several inches deep, Fountain was able to absorb the water, never filling to the point of overflow. Following an eruption of Morning, the water level in Fountain would drop out of sight, then gradually rise until the next eruption of Morning. Using rocks in Fountain's crater as markers, Fountain's water level at the time Morning erupted fluctuated. The longer the period between Morning's eruptions, the higher Fountain's water level would be. However, Fountain's water level never reached the point of overflow, even prior to the concerted eruptions with Morning.

After Fountain resumed eruptions on August 29 without Morning, Fountain's periods were quite variable. For example, following the August 29 concerted eruption with Morning, Fountain erupted at 2101, a period of 8 hours 47 minutes. The next recorded eruption was 0801 on August 30, a period of 11 hours, which was followed by a period of 8 hours 39 minutes. On September 1, consecutive periods were 6 hours 7 minutes, 4 hours 28 minutes, 7 hours 21 minutes, and 4 hours 22 minutes. On September 2, I recorded a period of 7 hours 43 minutes. And, on September 4, consecutive periods of 4 hours 40 minutes and 6 hours 20 minutes were recorded. Most durations were between 30 and 40 minutes. At that point, I concluded the system was not stable, decided to spend some time in the Upper Geyser Basin before I had to leave the Park, and stopped collecting data.

UNGFTN2 and Jet: During the time Morning was active UNGFTN2 showed much more variability in its activity than it had when

Fountain was active. The range of periods and durations increased, with periods ranging from 1.5 to 6.5 hours and durations ranging from 8 to 24 minutes. The observed periods hint that there might have been a cyclic pattern to this variation--periods would gradually shorten, reaching a low point, then gradually lengthen, reaching a high point, then start shortening again. However, because data was not collected round the clock and because observations of closed periods for UNGFTN2 became sparse after August 14, there is just a hint of this pattern, with no quantification possible.

On May 4 and May 5, each observed eruption of Morning was preceded by an eruption of UNGFTN2 with no intervening eruption by Jet, and I stated that UNGFTN2 seemed to act as an indicator for Morning. This happened again on August 10 for the first three eruptions of Morning, but then there were eruptions of Jet between the 1650 eruption of UNGFTN2 and the 1807 eruption of Morning. For the next four observed eruptions of Morning, UNGFTN2 preceded Morning with no eruption of Jet between the two. But the 1602 eruption of Morning was preceded by eruptions of Jet. On August 12, two eruptions of Morning were preceded by eruptions of Jet, and two were not. After that, eruptions of Morning were more likely to be preceded by eruptions of Jet than to be preceded by eruptions of UNGFTN2 without an intervening eruption of Jet.

The Jet eruptions between the 1650 eruption of UNGFTN2 and the 1807 eruption of Morning on August 10 appeared to be a function of the 4 hour 44 minute period for Morning before the 1807 eruption. But the period preceding the 1602 eruption of Morning on August 11 was only 3 hours 33 minutes. On August 12 periods for UNGFTN2 showed a significant increase, jumping from the three hour range observed on August 11 to observed periods on August 12 of 4 hours 13 minutes and 5 hours 39 minutes. On August 12, the first Jet eruption during an eruption of Morning was observed during the 1302 eruption of Morning. Then on August 13 the first Jet eruption during an eruption of UNGFTN2 was observed during the 0655 eruption of UNGFTN2. Although not frequent, Jet eruptions during eruptions of UNGFTN2 continued to be observed through August 28.

On August 10, Jet showed periods of quiet following an eruption of UNGFTN2 lasting 50 to 60 minutes, until 2059, when the 2059 eruption was followed by a period of quiet exceeding 3 hours 47 minutes. The duration of quiet periods following an eruption of UNGFTN2 on August 11 was not observed. Beginning on August 12, most eruptions of UNGFTN2 were followed by about a 20 minute quiet spell for Jet. Thus, it appears that it took 3 to 4 days of activity by Morning before relationships among Jet, UNGFTN2, and Morning started to stabilize.

In addition to changing the relationship between Jet and UNGFTN2, Morning also changed Jet's eruptive cycle. During an eruption of Fountain, Jet would erupt every 1 to 3 minutes. But during an eruption of Morning, Jet sometimes did not erupt. And when it did erupt, periods between eruptions were 12 to 20 minutes. Following an eruption of Fountain, Jet would be quiet for a time, and when it resumed erupting, the periods would start at about 10 minutes and gradually shorten to about 6 minutes. But after an eruption of Morning, Jet's periods would start in the 3 minute range and gradually lengthen to a 6-7 minute range just before Morning erupted again.

Clepsydra: Eruptions of Morning Geyser were not followed by Clepsydra pauses. However, during the last week of Morning's activity, Clepsydra was twice observed in a pause between eruptions of Morning. On August 20, Clepsydra began "coughing" (with bursts being separated by a few seconds) at 0950. Clepsydra came to a complete pause for eight minutes between 1032 and 1040. This pause happened 2 hours 2 minutes after the 0830 eruption of Morning and 1 hour 53 minutes before the 1225 eruption of Morning. On August 21, Clepsydra was observed to pause for 2.5 minutes from 1800 to 1802. This pause occurred 50 minutes before the 1850 eruption of Morning. On August 25, Clepsydra was "coughing" from 1657 until the start of the Morning eruption at 1850. No pauses of Clepsydra were observed on August 26, but Clepsydra was noted to be in steam phase prior to Morning's eruption for an hour, starting at 1840 and ending at 1940. Morning erupted at 1945. Previously, Clepsydra's steam phase activity had only been noted during Morning's eruptions. There was a visitor report that Clepsydra stopped for approximately 2 minutes on August 27 between the 1326 and 1630 eruptions of Morning. Because the Fountain Complex was not under continuous observation during the three weeks Morning was active, it is possible that Clepsydra's pauses between eruptions of Morning started before August 20. However, observers remained for 10-15 minutes after the end of Morning's eruption for almost all eruptions, so it is possible to state that Morning's eruptions were not immediately followed by a Clepsydra pause during the three weeks Morning was active.

Spasm: While Fountain was erupting, Spasm would usually erupt only once every 6.5 to 8.5 hours, with Spasm's eruptions starting 30 to 60 minutes before Fountain started, and ending about 5 minutes after Fountain started. It appeared that the influx of runoff from Fountain "drowned" Spasm's eruptions.

Once Morning started erupting and Fountain ceased, Spasm developed a different pattern. Between August 10 and noon on August 28, 31 closed periods for Spasm were observed. These averaged 3 hours 36 minutes, and ranged from a short of 2 hours 14 minutes to a long of 4 hours 31 minutes. Distribution of the periods (stratified into 15 minute segments) was fairly uniform--two of the 31 periods were less than three hours, four were 3 to 3.25 hours, seven were 3.25 to 3.5 hours, seven were 3.5 to 3.75 hours, four were 3.75 to 4 hours, and four exceeded 4 hours.

Water from Morning's eruption did not flow into Spasm. Eleven durations for Spasm were determined, ranging from 49 to 96 minutes, with an average of 67 minutes. Durations divided into ten minute segments between 46 and 96 minutes were evenly distributed among the segments.

Spasm's eruptions started with muddy water both when Fountain was active and when Morning was active. The water would clear 5 to 10 minutes into the eruption. While Fountain was active, it was believed that the cause of the muddy water was the fact that each eruption of Fountain sent water and accompanying debris into Spasm. But during the three weeks Morning was active, no debris was being washed into Spasm from the surface. So why did Spasm's eruptions continue to start with muddy water? Possibly accumulated silt and debris on the side of Spasm's crater caused the dirty water at the start of Spasm's eruption. Or possibly the debris washed by Morning into Fountain was moving directly into Spasm's upper level water reservoir(s) and being circulated quickly into Spasm's eruptions without allowing the water to percolate through layers of rock which would allow the particles to be removed.

From July 22 to August 9, most eruptions of Fountain were preceded by an eruption of Spasm. This relationship continued between Spasm and Morning. The status of Spasm's eruptive activity compared to Morning's eruptive status is known for 81 eruptions of Morning. For 60 (74%) of these, Spasm was in eruption when Morning started. Spasm started during Morning's eruption for 3 (4%) of the observations. For 18 (22%) of the observations, Spasm was not in eruption when Morning started and did not start while Morning was in eruption. When Spasm did start erupting before Morning erupted (47 observations where the exact lead time is known), the lead time by Spasm ranged from 1 minute to 59 minutes, with an average of 24 minutes. However, 2/3 of the lead times were less than 30 minutes. A visual examination of the data indicates that the longer lead times happened when Morning had longer periods.

CONCLUSION

Existence of complex interrelationships among geysers in the Fountain Complex has long been recognized. The fact that activity patterns of UNGFTN2, Jet, Clepsydra, and Spasm showed significant differences between the time when Fountain was active and the time when Morning was active in 1991 is not surprising. Extreme caution should be used in generalizing these observations beyond the statement that they exist. The relationships observed during the summer of 1991 may only occur when there is a combination of Fountain erupting at 6.5 to 7.5 hour periods with 40 minute durations and then Morning erupting from a low pool at 3.75 hour periods for 11-30 minute durations for an extended period of time. So all that can be said is "This is what happened in 1991". These observations may be used for comparative purposes, but not for predictive purposes about what may happen the next time Morning reactivates.

ACKNOWLEDGMENTS

If I tried to list everyone who contributed to the information summarized in this article and who assisted me during the long hours of observation of the Fountain Complex, I would undoubtedly forget someone. Thank you all. But special thanks to Rick Hutchinson for coming out in the late evening and early morning hours to set up the portacorder to record eruptions during the night. Without his efforts, this record would have been far less complete than it is.

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APPENDIX A

1991 ERUPTIONS OF MORNING GEYSER

DATE	TIME	PERIOD	DURATION	COMMENTS
May:				
5/04/91	0938ie		> 18m	Per Lee Whittlesey
5/04/91	1338	app. 4hr	16m	Per Gordon & Nancy Bower
5/04/91	1717	3hr 39m	18m	
5/04/91	2135	4hr 18m	17m	
5/05/91	0025	2hr 50m	18m	
July:				
7/04/91	1442	60d14h17m	31m	Concerted with Fountain, per T. Dunn's and Benders
7/05/91	1345	23hr 3m	21m	Concerted with Fountain
August:				
8/09/91	1924		38.5m	Concerted with Fountain Possibly one or two eruptions missed overnight
8/10/91	0516		10m	9 hr 52 m for one?two?three?
8/10/91	0925:35	4hr 9m	25m	
8/10/91	1323	3 hr 58m	13.5 m	
8/10/91	1807	4 hr 44m	23m 50s	
8/10/91	2159	3 hr 52m	28.5 m	
8/11/91				Eruption per markers
8/11/91	0529	3hr45m/2	18m	
8/11/91	0900:10	3 hr 31m	14m	
8/11/91	1228:31	3 hr 28m	22m 50s	
8/11/91	1602:13	3 hr 34m	15m	
8/11/91	1934:45	3 hr 32m	24.5m	
8/11/91	2305	3 hr 31m	25.5m	Per Schwarz and Koenig
8/12/91				Eruption per markers
8/12/91	0553:32	3hr24m/2	11m 33s	
8/12/91	0923:15	3 hr 30m	25m 0s	
8/12/91	1302:30	3 hr 39m	13m 50s	
8/12/91	1654:30	3 hr 52m	26m 10s	
8/12/91	2039:10	3 hr 45m	13m 50s	
8/13/91	0047	4 hr 9m	24m	Per Schwarz and Koenig

Although periods are reported to the nearest minute in this list, actual periods to the nearest second were used to compute statistics presented in the article.

APPENDIX A (continued)

1991 ERUPTIONS OF MORNING GEYSER

DATE	TIME	PERIOD	DURATION	COMMENTS
8/13/91	0423:50	3 hr 36m	19m 50s	
8/13/91	0800:30	3 hr 37m	16m 50s	
8/13/91	1128:00	3 hr 28m	17m 40s	
8/13/91	1518:30	3 hr 50m	22m 0s	
8/13/91	1937:50	4 hr 19m	23m 0s	
8/13/91	2318:58	3 hr 41m	25m 32s	
8/14/91	0311	3 hr 53m		per portacorder
8/14/91	0651:48	3 hr 40m	28m 57s	
8/14/91	1024:00	3 hr 33m	11m 40s	
8/14/91	1527:06	5 hr 3m	27m 24s	
8/14/91	1941:00	4 hr 14m	22m 25s	
8/14/91	2256	3 hr 15m		per portacorder
8/15/91	0232	3 hr 36m		per portacorder
8/15/91	0616	3 hr 44m	14.5m	per portacorder
8/15/91	0930:30	3 hr 14m	23m 30s	
8/15/91	1348	4 hr 18m	22m	
8/15/91	1718:40	3 hr 30m	23m 0s	
8/15/91	2052:44	3 hr 34m	19m 56s	
8/16/91				Assumed eruption
8/16/91				Eruption per markers
8/16/91	0728:50	3hr 32m/3	23m 15s	
8/16/91	1100:20	3 hr 32m	26m 40s	
8/16/91	1457:00	3 hr 57m	11m 30s	
8/16/91	1855:50	3 hr 59m	25m 30s	
8/16/91	2230:40	3 hr 35m	21m 5s	
8/17/91	0153	3 hr 23m	24m	Per Mike Keller
8/17/91	0533:10	3 hr 40m	19m 25s	
8/17/91	0913.29	3 hr 40m	21m 1s	
8/17/91	1253:30	3 hr 40m	20m 40s	
8/17/91	1654:05	4hr 0m	21m 15s	
8/17/91	2044:50	3 hr 51m	27m 0s	
8/17/91				Determined by marker
8/18/91	0425:00	3hr50m/2	26m 20s	
8/18/91	0819:45	3 hr 54m	15m 45s	
8/18/91	1200:00	3 hr 40m	18m 0s	
8/18/91	1551:10	3 hr 51m	17m 0s	
8/18/91	1953:08	4 hr 2m	29m 2s	
8/18/91	2351:19	3 hr 58m	14m 40s	Per Jens Day
8/19/91	0334:10	3 hr 43m	24m 40s	
8/19/91	0725:23	3 hr 51m	31m 57s	
8/19/91	1058:10	3 hr 33m	14m 50s	
8/19/91	1413:20	3 hr 15m	16m 8s	
8/19/91	1803:30	3 hr 50m	29m 0s	
8/19/91	2159:15	3 hr 56m	20m 30s	
8/20/91				Eruption per markers

APPENDIX A (continued)

1991 ERUPTIONS OF MORNING GEYSER

DATE	TIME	PERIOD	DURATION	COMMENTS
8/20/91				Assumed eruption
8/20/91	0830:04	3hr30m/3	23m 40s	
8/20/91	1225:28	3hr 55m	19m 20s	
8/20/91	1622:07	3hr 56m	20m 8s	
8/20/91	2003:10	3 hr 41m	24m 0s	
8/20/91	2329	3 hr 26m	15.5m	Per portacorder
8/21/91	0259	3 hr 30m	18m	Per portacorder
8/21/91	0658:53	4 hr 0m	23m 37s	
8/21/91	1053:45	3 hr 55m	29m 15s	
8/21/91	1448:30	3 hr 55m	13m 45s	
8/21/91	1850:48	4 hr 2m	24m 12s	
8/21/91	2248	3 hr 58m	21 2/3m	Per portacorder
8/22/91	0225	3 hr 37m	27m	Per portacorder
8/22/91	0611:00	3 hr 46m	14m 0s	
8/22/91	0937:29	3 hr 26m	16m 45s	
8/22/91	1311:30	3 hr 34m	19m 30s	
8/22/91	1710:13	3hr 59m	17m 37s	
8/22/91	2053:55	3hr 44m	18m 35s	
8/23/91	0028	3 hr 34m	29 2/3m	Per portacorder
8/23/91	0408	3 hr 40m	14.5m	Per portacorder
8/23/91	0737:00	3 hr 29m	20m 25s	
8/23/91	1106:15	3 hr 29m	15m 0s	
8/23/91	1444:10	3 hr 38m	22m 0s	
8/23/91	1912:10	4 hr 28m	30m 0s	
8/23/91	2303	3hr 51m	29.5m	Per portacorder
8/24/91	0231	3hr 28m	15m	Per portacorder
8/24/91	0603:05	3hr 32m	21m 5s	
8/24/91	1016	4hr 13m	23.5m	Per portacorder
8/24/91	1503:00	4 hr 47m	17m 50s	Very windy
8/24/91	1907:25	4 hr 4 m	28m 20s	Very windy
8/24/91	2237:30	3 hr 30m	25m 0s	Calm
8/25/91	0150	3 hr 13m	14 2/3m	Per portacorder
8/25/91	0500	3 hr 10m	26 2/3m	Per portacorder
8/25/91	0844:30	3 hr 44m	15m 0s	Calm
8/25/91	1222:10	3 hr 38m	22m 20s	Breezy
8/25/91	1706:22	4 hr 44m	26m 0s	Windy
8/25/91	2112:50	4 hr 6m	14m 10s	Windy
8/26/91	0036	3 hr 24m	23 1/3m	Per portacorder
8/26/91	0403	3 hr 27m	27m 30s	Calm
8/26/91	0735:05	3 hr 32m	13m 25s	Calm
8/26/91	1055:35	3 hr 20m	22m 40s	Calm
8/26/91	1528:50	4hr 33m	26m 40s	Windy
8/26/91	1945:15	4 hr 16m	24m 45s	Breezy
8/26/91	2303:55	3 hr 18m	13m 0s	Calm
8/27/91	0224	3 hr 20m	24 2/3m	Per portacorder
8/27/91	0550	3 hr 26m	13 1/4m	Per portacorder

APPENDIX A (continued)

1991 ERUPTIONS OF MORNING GEYSER

DATE	TIME	PERIOD	DURATION	COMMENTS
8/27/91	0927:15	3 hr 37m	21m 35s	Calm
8/27/91	1326	3 hr 59m	24 4/5m	Per portacorder
8/27/91	1701:20	3 hr 35m	23m 30s	
8/27/91	2015:05	3 hr 14m	23m 40s	
8/28/91	0011	3 hr 56m	29m	Per portacorder
8/28/91	0355	3 hr 44m	23 1/4m	Per portacorder
8/28/91	0745.45	3 hr 50m	18m 5s	
8/28/91	1138:15	3 hr 53m	11m 30s	Very weak eruption
8/28/91	1853	7 hr 15m	36m	Concerted with Fountain
8/29/91	1215	17hr 22m	27m 25s	Concerted with Fountain

Pinto Geyser in History:
Its "Arsenic", "Twentieth Century", and "Fireball" Alter Egos

by Lee H. Whittlesey

Abstract
An analysis of historical records indicates that the feature now known as Pinto Geyser is the same as that previously known as Arsenic Geyser, Twentieth Century Geyser, and Fireball Geyser. This confusing history is explained.

Has the present Pinto Geyser really carried all of those other names? Has it thus had its history clouded so as to confuse observers since earliest Yellowstone days? The answer is "yes" to both questions. The reasons? Pinto's hard-to-reach location in an area pockmarked with many overlapping and confusing springs, and its tendency (like many other Norris Geyser Basin springs) to change or stop its activity.

Historically, observers could not easily reach Pinto Geyser and so had to be content with viewing it and those springs near it from a distance. This situation caused Pinto to not be carefully monitored at times and to be ignored or forgotten during its dormant periods. The many nearby features added to the confusion, especially if they spouted, such as those north and southwest of nearby Lava Pool, because observers could not see them well enough from a distance. Just which spring was which out there?

Well... Just-what-was-what-out-there was confusing from the earliest days. Dr. A.C. Peale's 1878 map and tables for this area were difficult to make sense of even in the 1880s (as Walter Weed attested to in his various notebooks), and nearly impossible today. Just what today's Pinto, Constant, Whirligig, Little Whirligig, Fireball, and Fan Geysers were in Peale's writings are impossible today to determine. Peale's spring #15 ("a constant spouter, throwing a mass of water 5 feet into the air, [with] occasional spouts 15 to 20 feet") could have been today's Pinto Geyser, or today's Constant Geyser, or neither. About all we can say is that Peale's numbers 11 through 17 probably included the area encompassing today's six above-named geysers.

In Wonderland Nomenclature [Whittlesey, 1988], I have chronicled the history of old "Arsenic Geyser" and present Arsenic Geyser. Walter Weed's spring #15 (a spouter then) was named "Arsenic" by weed's boss Arnold Hague in 1887, and Weed's sketch map makes it clear that it was today's Pinto Geyser. The present Arsenic is a different geyser to the southwest. The hillside (or small ridge) which abuts Pinto on the east side was clearly shown by Weed on two maps in his notebooks. Pinto then was orange-lined in the center, black or gray in its outer portions, and seven feet in diameter when it was full of leaden colored water. Weed saw it erupt in 1887 to 25-30 feet but Hague later gave its height as only four feet. Perhaps it changed heights between 1887 and the time of Hague's mention.

At any rate, there are no further known references to "Arsenic" (Pinto) in the literature.

On January 3, 1902, the ice crew of the Yellowstone Park Association was on its way to the Norris Hotel from Lower Basin. While passing through Porcelain Basin, they unexpectedly saw a "new" geyser in eruption to heights of around forty feet. By January 31, acting superintendent John Pitcher had given it the name "Twentieth Century Geyser", or had taken the name from local usage, and had written to park tour guide G.L. Henderson about it [Pitcher, 1902]. Pitcher located the geyser "135 feet east of the Constant geyser" and stated that its crater was "26 1/2 by 41 inches." He noted that its eruptions were similar to those of Constant Geyser but six times greater in volume, with intervals of 1 1/4 to 1 5/6 hours, and durations of 8 to 11 minutes. Pitcher sent the information to geologist Arnold Hague on February 18, and noted the occurrence in his annual report.

Pitcher's information was timely enough to make it into William F. Hatfield's small-sized guidebook, Geyserland and Wonderland [1902], although Hatfield got confused about the location of "Twentieth Century Geyser." Hatfield did note, however, the factor that has made the spring so difficult to track: that its eruptions were "liable to change without notice."

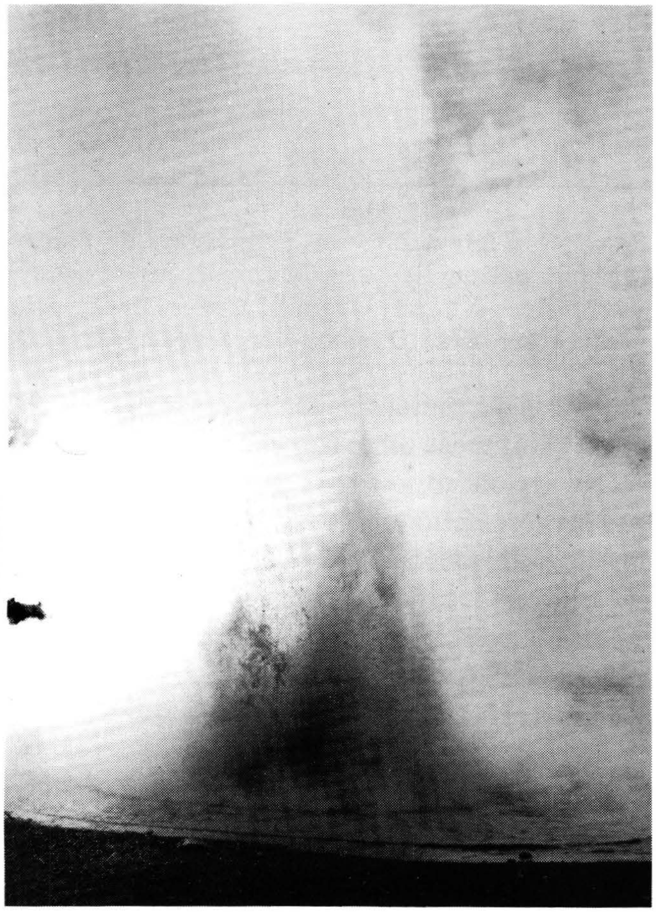
Hague appears to have seen the geyser on his visit of that year. he observed:

> The Twentieth Century broke out in the early spring, along the same fissure or vent as the Minute [Constant] Geyser. The new geyser plays every hour and a half, the picturesque column throwing out side jets similar to the Constant. The water gradually fills the saucer-like depression, after which the eruption plays for 15 minutes, when it all recedes into the vertical tube, very little running off... The vent is about one foot long...[Hague, 1902].

Only one further mention of "Twentieth Century Geyser" is known, that of Charles Heath who saw it in 1905, noting that it was "formerly a hot spring, but now a good geyser of regular eruption" [Heath, 1905].

There is no reference to "Twentieth Century Geyser" in Hague's 1904 Atlas of maps. In fact, as with so many of that Atlas's thermal spring names, the name "Arsenic" is shown on the map in such a way as to make it difficult to determine a definite location for the feature. So we have no way of knowing from the map whether Hague had determined or not that "Twentieth Century" was Weed's "Arsenic", nor anything else about old "Arsenic" or about "Twentieth Century Geyser."*

A field check of the Pinto area on April 20, 1991, convinced me that present Pinto Geyser is Pitcher's "Twentieth Century Geyser." The spring is indeed about 135 feet east of Constant Geyser and probably is or would have been on the same fissure. The vent of the mottled spring (for which appearance naturalist Ed Leigh gave the name Pinto in 1970) is indeed about 26 by 41 inches. Nothing else in the vicinity fits Pitcher's descriptions, certainly not the Lava Pool complex to the south, nor Primrose Springs to the east of the low ridge. Additionally, present Pinto could square with Weed's 1887 descriptions of "Arsenic Geyser."†



Pinto Geyser, former Arsenic–Twentieth Century–Fireball, as it looked during the disturbance of August, 1974. Photo by T. Scott Bryan.

One final point needs to be made, that of Pinto's also being the original "Fireball Geyser." Rocco Paperiello makes this argument convincingly in the accompanying article [Paperiello, 1992], "Will the Real Arsenic Geyser Please Stand Up?" Essentially, both the 1959 map by Al Mebane and the 1966 map by Jerome

* Rocco Paperiello argues that on the Norris map in the Hague Atlas some geyser locations are pinpointed by a sunburst symbol. If this is true, then "Arsenic" of Hague and Weed is indeed shown as being present Pinto Geyser.

† Had I discovered ten years ago that present Pinto Geyser was "Twentieth Century Geyser", I probably would have pushed for restoration of the old name and the dropping of the name Pinto. But I now believe there is too much "water under the bridge" to change the name back.

DeSanto show the name "Fireball Geyser" on the pool of the present Pinto Geyser.

I cannot explain how the name Fireball was eventually moved to its present location somewhat to the west except to say that it is probably a testimonial to the power of this area to confuse naturalists, tour guides, and geyser gazers. Personnel at Norris, GOSA members, and others must take care to be specific about locations of springs we discuss. We must draw maps when possible and use careful descriptions like Pitcher's. Confusion is the result when we do not do this, and errors get made.

As so, a few more pieces of the historical geyser puzzle have been fitted together, this time with regard to the alter egos of Pinto Geyser. There are many more such pieces to be found where Norris Geyser Basin is concerned, because the area is indeed a changeling. As G.L. Henderson, that imaginative old coot who so loved Yellowstone, wrote in 1902: "A guide book for Norris Basin should be revised every two years."

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Will the Real Arsenic Geyser Please Stand Up?

by Rocco Paperiello

Abstract

The identity of Arsenic Geyser has been confused throughout Yellowstone Park history, and the names Fan, Fireball, Twentieth Century, and Pinto have all apparently been applied to the same feature. This history is clarified.

For years we have read Scott Bryan's comment in his *The Geysers of Yellowstone* on Fireball Geyser of the Norris Geyser Basin. He believed that some name switching had taken place, stating: "...we now have a non-fan-shaped geyser named Fan and a fan-shaped geyser named Fireball."

To help explain this situation we can go back to maps drawn by Al Mebane in 1959 and Jerome DeSanto in 1966. It is clear from these maps that:

1) today's fan-shaped "Fireball Geyser" was indeed the original Fan Geyser;

2) the name "Fan Geyser" has been subsequently moved to a previously unnamed vent about thirty feet to the northeast of today's "Fireball";

3) the original Fireball Geyser erupts from a small pool we know today as "Pinto Geyser"!

But to add even further convolutions to this name switching story we must go back to the 1880's. It was in 1887 that Arnold Hague first named Arsenic Geyser. And yes, you guessed it, it is not the same feature we call Arsenic today. On Geology Sheet XXI of his 1904 Atlas, Hague clearly shows the name of "Arsenic" attached to a feature in the position of today's "Pinto Geyser." (This interpretation of the name's placement becomes clear when we realize that, except for the larger pools, this Sheet used the sunburst symbol (R)to designate the placement of its geysers.) In addition, the earliest descriptions of Arsenic Geyser describe it as erupting from a small pool. A final clarification comes from a sketch map of the area, along with a brief description, found in one of Walter Weed's 1887 formal notebooks:

> 15 Arsenic Geyser
>
> Eruption observed July 8th/87. 25'-50' -12:05 pm -20 min duration
>
> Funnel shaped basin 7 ft in diameter when full. Orange lined center; black or gray outside. Water milky. Leaden colored, but not muddy. Was supposed to be a new geyser by the soldiers who report that it spouts for 4 hours.

The placement on Weed's sketch map clearly places this geyser again in the position of today's "Pinto Geyser" (and yesterday's "Fireball Geyser") which Hague originally named Arsenic Geyser.

But the story is not quite over. It seems that during yet another rejuvenation of this geyser it may well have acquired still another persona. It was recently pointed out to me by Lee Whittlesey that the geyser named "Twentieth Century" could also be placed in about the exact spot of today's "Pinto Geyser." I had the following article from the *Livingston Post* but failed to make the necessary connections. In the February 6, 1902, edition we read the following excerpts from an article by G.L. Henderson entitled "Norris Geyser Basin":

> Mammoth Hot Springs, Jan. 31 — Maj. John Pitcher, superintendent of Yellowstone National Park, informed your correspondent that on the third of January, the ice crew of the Yellowstone Park association, coming from the Lower Geyser Basin, had their attention drawn to an unexpected and entirely new exhibition of volcanic action on the Porcelain Basin: This Twentieth Century geyser is situated 135 feet east of the Constant geyser. Its crater is 26 and one-half inches wide and 41 inches in length. Its eruptions are very similar to those of its neighbor, the Constant, only about six times greater in volume. The length of the eruptions vary from 8 to 11 minutes and at intervals from 1 and one-fourth to 1 hour and 50 minutes.
>
> The Norris Geyser Basin during the last 25 years has presented a phenomenal succession of annual surprises— the Twentieth Century being one...

In his notes of his various trips to the geyser basins of Yellowstone Park, Arnold Hague adds the following:

> August 5, 1902.— Norris Geyser Basin. Walked over most active part of the basin in the afternoon, staying for some time in the region of the Growler and New Boiler.
>
> The New Boiler broke out during the night sometime in February, 1902...
>
> The Twentieth Century broke out in the early spring of this year, the same fissure or vent as the Minute [Hague uses Minute and Constant interchangeably]. It plays an hour and a half, a beautiful column, throwing out side jets similar to Constant. The water fills the saucer-like depression, then plays for fifteen minutes...

If this geyser "breaks-out" again in the future, will it be given yet another name? In any case, to summarize: today's Fireball is the original Fan; today's Fan was previously unnamed; today's Pinto was the original Fireball, but it was also previously known first as Arsenic (its proper name, therefore) and later as Twentieth Century; today's Arsenic is a previously unnamed, small, conical, sinter-lined vent a foot across southwest of Lava Pool.

While this portion of Norris Geyser Basin has had a long history of confused names, the modern identities were apparently established sometime after DeSanto prepared his map in 1966, most likely by Ed Leigh and the other seasonal naturalists in 1970 or before. It is curious that the 1966 work should have been forgotten so quickly, but Scott Bryan possesses photos taken in 1970 which are clearly labeled with today's naming.

[Editor's Note: The editor would also like to point out that due to all of this long standing confusion, it is impossible to relate names to statistics in references such as the Haynes' and Hamilton's guide books. tsb]

Today's Fireball Geyser, erupting fan–like from several vents. Photo by T. Scott Bryan, August, 1974.

Eruptive Activity By Black Pool, August 15, 1991

West Thumb Geyser Basin
Yellowstone National Park

by Allan Friedman

Abstract

Black Pool had never been known to erupt prior to August 15, 1991. After a month or so of gradual heating, an apparent steam explosion led into a short series of eruptions, which concluded on the same date.

Introduction

Black Pool, just southeast of Abyss Pool in Yellowstone's West Thumb Geyser Basin, has been a very dark colored warm pool with algae growing along the sides of the crater. It has never been known to erupt.

From available historical records dating from 1961 to 1987, the pool's temperature has ranged from a low of 103°F (Winter, 1982) to a high of 160°F (June, 1970).

One recent report, however, states: "On the north edge of Black Pool a small vent was first observed on July 17 [1990]. The temperature was 178°F at that time but has since decreased to 169°F on October 12." This vent appeared to be the energy source for the 1991 eruptions.

1991 Eruptions

This summer [1991] the temperature in both Black and Abyss Pools rose. Abyss Pool became as hot as 203°F while Black Pool reached 178°F. The algae along the sides of Black Pool died, and the spring turned a bright blue.

On the morning of August 15, I went to West Thumb to see the "new" Black Pool. As I approached from the south, I noticed runoff channels containing silty, milky-colored water. Those channels led me to Black Pool, which I found neither black nor blue but rather a gray-brown, partially silty and partially muddy colored.

In the northwest portion of the pool was an area that was boiling. It seemed that the pool had either erupted or overflowed very heavily. There were both pools of still-hot water near the rim and areas that were wet though not pooled.

I waited and, at 11:53, the boiling picked up and the boiling area erupted to about 1 foot high with waves and heavy overflow. The duration was about 30 seconds. After the eruption the water level in the pool dropped and overflow almost stopped.

After this eruption, I observed the following:

1. Ar ound the area where the boiling and eruption occurred there were a number of sinter chunks scattered in a semi-circle more than 20 feet across. The largest of these pieces were nearly a foot in diameter. This indicated a steam explosion.
2. The silty runoff could be seen entering the lake.
3. There were newly eroded muddy channels extending toward the lake, evidence of recent and much heavier overflow than I saw.
4. The algal mats, in all areas around the pool, were thoroughly silted and dying. These mats still showed a good deal of red color when I arrived, but the color had almost all faded when I departed at 18:30.
5. After the eruptions, there was a large patch of muddy water at the south end of the pool which washed out with each subsequent overflow.
6. The temperature of the pool was measured by a naturalist as 178°F.

The eruptions I witnessed were all about the same duration (30 to 43 seconds), but increased in intensity, height, and width until they stopped. The last was over 2 feet high and 3 feet wide and released a very large overflow.

After the last eruption (I witnessed seven), there were two additional periods of heavy boiling and overflow— incipient eruptions— but then the pool seemed to stabilize. I temporarily left the site at 14:21 and returned at 16:21. There were no intervening eruptions.

From 16:21 until 18:30 the pool remained high with constant overflow and steady gentle boiling. Most of the boiling was in the northwest area, with a few added spots. The pool was stable during this period, maintaining a water level about the same as that immediately before the observed eruptions. The pool retained its gray silty color although the mud had cleared from the south edge of the spring by the end of the observation.

During this time I spoke with two naturalists and a volunteer who had come to view the incident. I was told about the spring(s) near the north edge of the pool, which had been measured as above boiling. Those springs were no longer visible.

I returned twice more to the area.

On August 17 Black Pool was beginning to clear. The color was a gray-green. Silt could be seen lining the edges of the pool. No boiling was observed while there was gentle overflow from the north, east, and south sides of the crater.

On August 21 the pool was becoming a clear greenish blue. Gentle overflow continued and there was no boiling. Most striking was the clarity of the water. For the first time I was able to see the area around the apparent steam explosion along the north edge of the pool.

Along that edge was a large piece of sinter, about six to eight feet long and one or two feet wide. It had been broken from the rim and was lying along the side, slanting into the pool. This was apparently due to the steam explosion.

Summary

Sometime during the spring or early summer of 1991, a portion of the West Thumb Geyser Basin heated up. This included Black Pool, a small unnamed spring on its edge, and Abyss Pool. On the morning of August 15 there was an explosion at the site of the small spring. This let the water of the spring, superheated and much hotter than that of Black Pool itself, flood into Black Pool, causing the witnessed eruptive behavior.

[Editor's Note: This activity unquestionably took place as a first-observed event accompanying a major exchange of function at West Thumb. This culminated in major eruptions by nearby Abyss Pool and a dramatic decrease in activity in the central portion of West Thumb. This activity was continuing as late as March, 1992. tsb]

Notes on Buried Geyser

Lone Star Geyser Basin
Yellowstone National Park, Wyoming

Gordon R. Bower

Abstract

Buried Geyser, a significant but little-known feature near Lone Star Geyser, was visited on two occasions during the 1990 season. This paper is a discussion of the eruption types and patterns that were observed.

Physical Description

Buried Geyser is located approximately 1/2 kilometer southeast of Lone Star Geyser, on the opposite side of the Firehole River. Steam from eruptions is visible from several points along the Kepler Cascades-Lone Star trail. The site can be easily reached starting from the bank of the Firehole River opposite Lone Star Geyser by entering the forest and following the base of the ridge until the extensive sinter deposit is reached.

Buried Geyser stands in a steep, narrow ravine opening into a small clearing in the forest. Fallen trees and boulders are clustered around and above the vent where the hillside has slumped toward the crater. According to [Bryan 1986] the name was given because of a sinter ledge over the crater that has since been destroyed, but "Buried Geyser" remains an apt description of the feature. The crater, filled with rocks having only a thin buildup of geyserite on them, measures about 3x4 meters. The vent appears to be about 1½ meters square. The water contains enough suspended silica to be nearly opaque. A large terrace extends to the base of the hillside below the geyser itself. The hillside above is dotted with small steam vents.

Observed Activity

The water within the vent slowly rose during the interval. Only a few minutes after one eruption ceased, gentle boiling resumed. The first surges usually occured about one minute later. These gradually built into the eruption. For the purposes of data collection, the start of an eruption was defined to be two splashes to more than 30 cm less than two seconds apart.

The eruptions were of three distinct types. For lack of better designations, these were referred to as minor, medium, and major.

Throughout the three-minute duration of a minor eruption, the water level gradually rose. Bursts were 1-3 meters high and generally confined to the crater. Just as the first trickles of water were beginning to escape into the runoff channel, the eruption ceased rather abruptly. With a minute the water had dropped to its original level, about 70 cm below overflow.

A medium eruption could be recognized as such only seconds after it began. The water level rise was much more rapid, reaching overflow in less than two minutes. Bursts, especially early in the eruptions, tended to be more violent than a minor's. Durations were similar to a minor's, three to four minutes.

A major eruption began in the same fashion as a minor, reaching overflow after three minutes of comparatively weak splashing. Rather than stopping at this point, the eruption became much more violent. Water poured down the runoff channel. Bursts frequently reached five meters in height, sometimes landing outside of the crater. One exceptional burst fell a full seven meters below the vent. The violent phase of the eruption usually lasted another two minutes, then ended as abruptly as all the other eruptions did.

Intervals (times between successive starts) were quite consistent around eight minutes for minors, ten for minors, and twelve for majors. The amount of data gathered was not sufficient to develop a method of predicting what type of eruption would occur next. Using the above classification of eruptions, the statement in [Bryan 1986] that consecutive majors do not occur holds true, but two consecutive eruptions might both have overflow.

The same three types of eruptions were observed on both visits. However, the distribution of eruption type had changed considerably-- 3 minors, 1 medium, 3 majors in June versus 3 minors, 7 mediums, 8 majors in October. This suggests that there may be a relatively long-term cycle, beginning exclusively with minors and culminating with numerous mediums and majors clustered together. Observation periods longer than the 1½- and 3-hour stays on which this paper was based would be necessary to determine whether or not this is true.

Reference

[Bryan 1986] Bryan, T. Scott. The Geysers of Yellowstone. Boulder, CO: Colorado Associated University Press, 1986.

Statistical Summary

Duration
- All-- 3m44s. StDev=40s. N=25
- Minor-- 3m14s. StDev=25s. N=6
- Medium-- 3m24s. StDev=30s. N=8
- Major-- 4m14s. StDev=31s. N=11

Interval
- All-- 10m17s. StDev=1m23s. N=23
- Minor-- 8m27s. StDev=25s. N=4
- Medium-- 9m27s. StDev=28s. N=8
- Major-- 11m34s. StDev=32s. N=11

Length of Eruption Prior to Overflow
- Medium-- 2m00s. StDev=35s. N=8
- Major-- 2m08s. StDev=32s. N=11

Duration of Overflow
- Medium-- 1m24s. StDev=20s. N=8
- Major-- 2m07s. StDev=11s. N=11

Overall Time in Eruption: 36.3%

Raw Data

June 30, 1990

1st Splash	Start	Overflow	Stop	Type
1508.45	1510.50	---	1513.37	Minor
1517.58	1519.24	1521.30	1523.37	Major
1529.56	1530.50	---	1534.29	Minor
1538.06	1539.19	1542.05	1544.14	Major
1550.21	1551.31	1553.03	1554.54	Medium
1558.07	1600.22	1603.24	1605.38	Major
1610.34	1612.28	---	1615.53	Minor

October 5, 1990

Boil	1st Splash	Start	Overflow	Stop	Type
0924.13	0925.30	0927.21	0929.12	0930.42	Medium
0933.35	0934.55	0936.55	0938.40	0940.38	Major
0944.35	0945.31	0947.59	0949.34	0950.48	Medium
0954.30	0955.20	0957.37	0959.33	1001.35	Major
1006.05	1007.03	1008.50	---	1011.31	Minor
1013.44	1014.29	1016.43	1019.36	1021.17	Major
1025.02	1026.22	1027.53	1029.57	1031.44	Medium
1035.19	1036.26	1038.16	1039.56	1042.07	Major
1045.57	1046.45	1049.32	1050.50	1052.27	Medium
1055.43	1056.49	1059.03	1100.44	1102.54	Major
1107.23	1108.08	1110.24	---	1114.04	Minor
1116.26	1117.29	1119.16	1121.14	1123.13	Major
1127.24	1127.47	1130.29	1132.28	1133.35	Medium
1136.14	1137.28	1139.33	1141.04	1143.25	Major
1147.48	1149.05	1151.08	1153.40	1154.36	Medium
1157.44	1158.21	1200.14	1203.22	1204.34	Medium
1207.04	1207.54	1209.41	1211.51	1214.17	Major
1219.17	1219.41	1222.24	---	1225.38	Minor

Observations at Shoshone Geyser Basin
July 17–18, 1991

by Jeff Cross

Abstract
In narrative form, observations conducted at the Shoshone Geyser Basin are summarized. Explanatory comments have been added by the editor of the *Transactions.*

The following information was gathered during an observational trip to the Shoshone Geyser Basin on July 16-18, 1991. The following does not expect to include all geysers active at Shoshone, but rather encompasses only those where significant observing time was spent. In recording features and activity, I have checked the names and USGS spring numbers for accuracy against Paperiello [1989]; and other unnamed geyser designations are from Bryan [1986].

[This paper has also provided the editor with the opportunity to add some bracketed [ ] comments of clarification and little known facts.]

Little Giant Group

Trailside Geyser. After evading observation in 1990, Trailside erupted on both July 17 and 18; in part, however, the activity was somewhat different from that reported before. On the 17th, it was its usual self, reaching 1 meter high on intervals of 5 to 10 minutes (average about 7 minutes) and with durations of 30 to 50 seconds. On the 18th, though, only a single eruption was observed. It was "normal" but was followed by what appeared to be a series of aborted eruptions.

A small spring on the southwest sinter apron of Trailside had a small (5 centimeters high) eruption on the 17th. [Observed previously, this small geyser is infrequently active and generally not enumerated in tabulated lists of Shoshone activity. *ed.*]

Double Geyser. Double was extremely regular throughout the observation period. Checked start-to-start intervals were almost clocklike in their 62 minute regularity. The eruptions reached heights of 2 to 3 meters and had durations of 6 to 10 minutes (although this is difficult to determine, as Double apparently hasn't figured out the concept of "end".)

Little Giant. Little Giant experienced minor eruptions during and following eruptions by Double. All the eruptions seen consisted of heavy splashes, reaching 1 to 2 meters. The vigor of the activity gradually declined during the 5 to 15 minutes following Double. Another significant eruption was also seen about 5 minutes prior to a Double eruption.

Unnamed geyser north of Little Giant. The activity of this small geyser consisted of 5 to 10 centimeter sputtering, which began some 5 to 15 minutes after an eruption of Double ended. The action continued without significant pauses until the next eruption of Double. Then the play would reach up to 50 centimeters for a few minutes, only to pause briefly at about the end of Double.

Meander Geyser. Meander was seen in eruption once. Preceded by several minutes of overflow, the lazy splashing to less than 1 meter lasted an undetermined time.

Locomotive Geyser. Locomotive was not seen in eruption, though it appeared to be active.

Minute Man Group

Soap Kettle. Soap Kettle apparently has two types of eruptions: minors and majors. The majors differ from the minors in that they discharge more water, involve a higher water level within the crater, and reach a greater eruption height. The bursts of some majors reach greater than 2 meters above the top of the cone, whereas the minors are no more than half as high. There is no correlation between the type of eruption and the statistics: intervals range between 4 and 11 minutes; durations from 3 to 8 minutes.

Little Bulger Geyser. The east vent ["Little Bulger's Parasite"] was active as a geyser. No eruptive action was seen from Little Bulger itself.

USGS #11. This feature functioned as an intermittent spring with intervals of about 10 minutes and overflow durations of 1 to 2 minutes, except when cooled runoff from Shield Geyser flowed into the crater. Then all noticeable activity stopped until 20 to 40 minutes after Shield's overflow ceased. The overflow periods involved a heaving of the water and gushing discharge down the bank and into USGS #12 below. The overflow was often accompanied by boiling, which tended to get stronger and even reach superheated conditions several cycles after the overflow from Shield had ended. [On infrequent occasions, this spring's bubbling is strong enough to break the water surface, so #11 is classed as a geyser; very rarely, it has been known to splash as great as 1 foot high.]

USGS #12. USGS #12 is a large, deep pool at the base of the bank on which USGS #11 is located. It functioned as an intermittent spring with intervals of 1 to 3 minutes and durations of 1 to 2 minutes. The overflow periods involved heavy discharge and, on occasion, steam bubbles darted into the crater. Sometimes, one of these bubbles was large enough to reach the surface and produce a small splash.

The data obtained for #11 and #12 indicates a possible activity relationship, in that some of #12's intervals were slightly longer and durations slightly shorter at about the time of #11's overflow.

Five Crater Hot Spring. This functioned as a geyser during the morning of the 17th, with eruptions occurring on intervals of 4 to 5 minutes. The eruptions consist of heavy overflow, a rocking of the water level in the two small pools, and 1 meter jetting out of the cracks and slits that make up the remainder of the feature. As with #11, the activity of five Crater is diminishes when it receives runoff from Shield Geyser. [It is the editors opinion, now agreed to by others, that Five Crater Hot Spring does not merit the designation as geyser: the jetting indeed rises from the miscellany of cracks and slits, but is believed to be a result of the surface surging rather than gas action— somewhat unfortunate, as Five Crater is an otherwise fascinating spring.]

Rosette Spring. Rosette showed no signs of the intermittent action previously reported.

Minute Man and Company. Minute Man's Pool behaves as I have always observed it to, overflowing for some time before an active cycle of Minute Man starts, lowering its water level during an eruption of Minute Man, and surging back up when Minute Man stops. Rumor has it that the Pool erupts near the end of an eruption series of its close neighbor, but I have yet to see it do so. [All the above is true. When the Pool had its major activity during the 1970s, the eruptions began after vigorous bubbling in a full crater. During episodes of lesser action, the eruptions tend to occur late in a Minute Man series at the time Minute Man starts playing and produces the water level drawdown in the Pool. Note, though, that usually no eruptions of any size take place.]

Orion Group

Union Geyser. Union was its usual dormant self, although the water level was observed to vary a bit.

USGS #86a. A geyser in 1989 and 1990, this year the most activity seen from this spring was an intermittent rising and falling of the water level.

White Hot Spring. This apparently was active as a perpetual spouter, splashing to 10 to 50 centimeters from a low water level.

UNNG-SHO-1 ("Sea Green") and UNNG-SHO-3. Both of these features appeared to be functioning as intermittent springs. The water level in SHO-3 appeared to be higher than it was in 1990.

North Group

Lion Geyser and Company. Lion was not seen in eruption, nor were any of its close associates. Wet sinter about the vent indicated some possible, unobserved rises in the water level.

Iron Conch. Iron Conch appeared to have both major and minor eruptions. Minors began after a short period of rest following a major while the water level was still low. Each successive minor brought the water level a bit higher, eventually resulting in some light overflow. The majors differed from the minors in that the play is stronger and overflow greater. Intervals ranged from 3 to 5 minutes, durations from 1 to 2 minutes.

Frill Spring. The most significant activity from Frill was a brief, 1 centimeter rise in water level accompanied by a small amount of turbulence. This action was seen only once, and apparently Frill did nothing of note when not under observation.

Knobby Geyser. Knobby erupted in series fashion this year. Two of the eruptive episodes were watched closely, and similar patterns were noticed at other times.

After a long period of quiet, Knobby had minor eruptions on intervals of 9 to10 minutes, and then experienced a major after an interval of 15 to 20 minutes. As the time of a major approached, the durations and water output of each minor increased. Major eruptions lasted about 5 minutes and threw water to heights of up to 8 meters.

After the eruptions, the crater emptied. During the intervals following minor eruptions, the geyser remained quiet until the next eruption. But after major eruptions the water immediately rose again and began thrashing about to less than 1 meter. As time progressed, pauses in the thrashing became more frequent and lasted longer, but also the thrashing play became stronger (reaching as high as 2 meters). However, after about 30 minutes of this action, instead of the play becoming minor eruptions, Knobby would enter a rest period of about 45 minutes before minors would resume.

The observed intervals between minor eruptions within a series was 8 to 10 minutes, with durations of only a few seconds. The intervals between the last minor and concluding major were recorded as 17 and 19 minutes. The single recorded interval from major to major was 1 hour 56 minutes.

Features Northwest of Knobby. A few paces northwest of Knobby is a small vent. Known as a small sputtering geyser in the past, this vent was almost undetectably obvious in 1991. Several more paces northwest is a collapsed crater (USGS #54); just beyond it is a small pool (USGS #53), and then a beautiful funnel-shaped spring (USGS #52). While both #52 and #53 are said to be geysers, they behaved only as intermittent springs without significant overflow. [USGS #52 is believed to equate with the Bead Geyser of the 1800's USGS explorations; a few will opt in favor of #54.]

Velvet Spring. Velvet had a single eruption to less than 1 meter. Otherwise, only intermittent overflow and light boiling was seen from it.

USGS #60, #61, and #62. These three features lie west of Velvet Spring. #60 is a double vented pool; although it has functioned as both a geyser and an intermittent spring in the past, this year it was inactive and sported a lining of orange algae. #61, also known as Fissure Spring [controversial], consists of one fissure vent and three smaller vents a meter to the fissure's east; a new-looking runoff channel contained a clump of grass, dead around the margins but still living on the inside. #62 is a wide funnel-shaped spring.

Both #61 and #62 were seen erupting as geysers together; #60 showed its relationship by draining as the other played and refilling with them. Two eruptions were seen from the start, another was seen in progress, and others certainly took place during our time at Shoshone. The activity begins with progressively stronger intermittent overflow periods from #62 (going from "seeping, to heavy, to massive, to extra-massive, to impressive"), but it is actually #61 that first starts to erupt. It is quickly joined by #62 and the water level rapidly drops in #60. Both geysers reach about 1 meter in height,

#62 lasting longer. Durations are about 10 minutes. Filling in gaps in the data, it appeared that the intervals were between 3 and 6 hours. [Very nice observation— in all my great many days at Shoshone, I have never observed eruptive activity in any of these three features.]

South Group

Outbreak Geyser. Outbreak's intervals were quite regular at 28 to 33 minutes. Estimated heights were 3 to 6 meters, and durations about 2 minutes.

Coral Pool. This feature functioned as an intermittent spring.

West Group

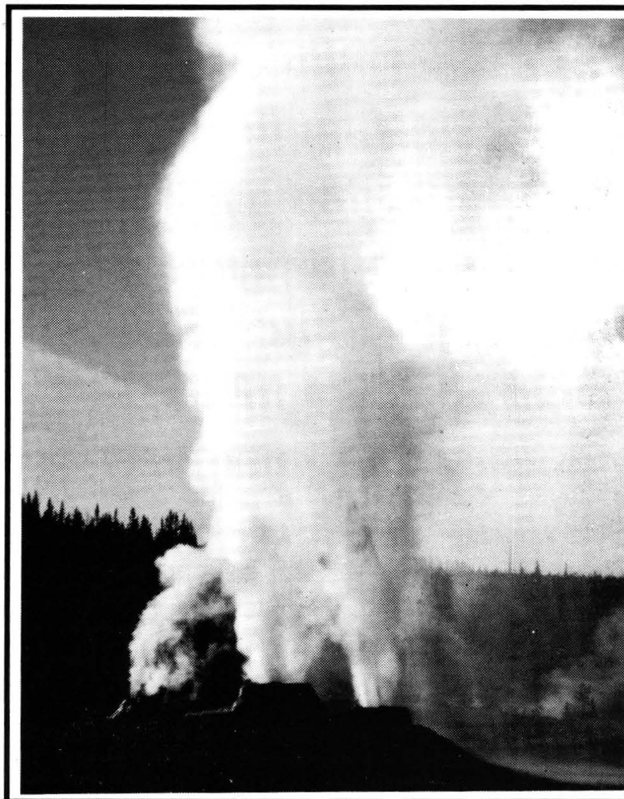
UNNG-SHO-9 (Pecten Geyser). Pecten was caught in the latter stages of an eruption once. Several of the bursts were seen to reach about 1.5 meters. Either the intervals were longer than 10 minutes or were irregular, as nothing other than quiet gurgling was seen at other times.

References Noted

Bryan, T.S., 1986, The Geysers of Yellowstone; Second Revised Edition: Colorado Associated University Press, Boulder.

Paperiello, R., 1989, Hot Springs of the northern part of Shoshone Geyser Basin, Yellowstone National Park, Wyoming: Geyser Observation and Study Association, Transactions, Volume I, New Haven, Connecticut.

Minute Man's Pool, as its major eruptions appeared during 1976. Photo by T. Scott Bryan



An eruption of **Union Geyser** in August 1976. Photo by T. Scott Bryan

Hot Springs of the Central Part of the Shoshone Geyser Basin, Yellowstone National Park

Rocco Paperiello

Abstract: A detailed set of tables and maps make up an inventory of the hot springs and geysers of the central portion of the Shoshone geyser Basin. An historical review of Union Geyser is presented Finally, information concerning the current activity and the identity of Lion Geyser along with a nearby "new" geyser is presented.

The tables and maps of this report are part of a comprehensive report on the Shoshone Geyser Basin that is currently in progress. The tables attempt to correlate material from a number of important sources about the features of this basin. The first column gives the number within the group designated by the author, and shown on the map. The next column gives the name; if it is an official name, it is presented in boldface. The next three columns list the designations used in [Peale 1883], [USGS 1966], and [Bryan 1986] respectively.

A previous portion of this report on Shoshone Geyser Basin was published in the 1989 GOSA Transactions; this report included the Little Giant, Minute Man, North, and South Groups. This present portion includes tables and maps for the Union, Camp, Island, Western, and "Horse Camp" Groups.

ORION GROUP

An interesting speculation put forth by Paul Strasser concerns the origin for the name of the Orion Group, along with that of Taurus Geyser.

Paul postulated that perhaps the three cones of Union Geyser were likened to the three stars in the belt of Orion, thus giving rise to the name of the group. It seems possible that the name Orion Geyser may have originally been attached to Union Geyser, and thus the group name was derived from its most prominent member as was a common practice of the Peale survey members.

Continuing this line of reasoning, Paul surmised that Taurus Geyser derived its name from the fact that the three cones of Union Geyser generally point to Taurus, just as the three stars in the belt of Orion point to its neighboring constellation of Taurus. (See Diagram #1).

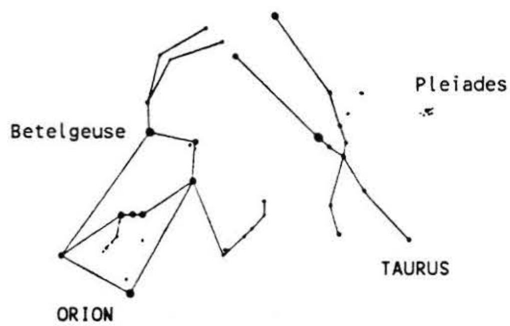
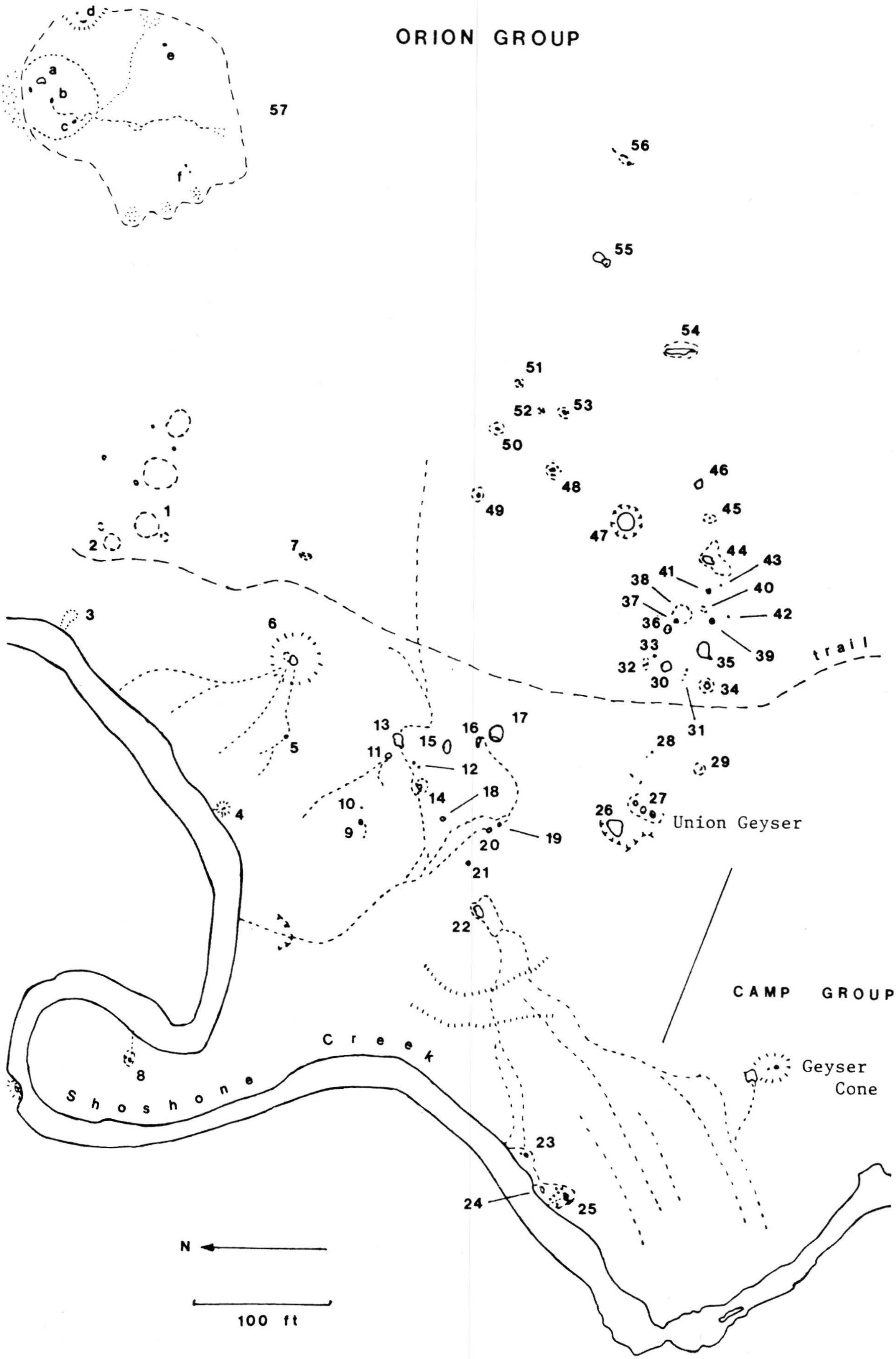


Diagram #1

SUMMARY OF GEYSERS BY GROUP

Group	Definite	Possible	Active in: 1987	1988	1991
Little Giant Group	8		7*	8*	6*
Minute Man Group	12		9	9	9
Orion Group	16	1	1	2	3
Camp Group	4		2	2	3
Yellow Crater Group	1		1	1	1
North Group	24		17^	13^	15^
South Group	8		4	3	3
Island Group		2	2~	0	0
Western Group	6		2	2	4
Shore Group	1		0	0	0
"Horse Camp Group"	2		2	0	2
"Swamp Lake Group"		2	1~	0	1~
	82	5	45(48)	42	46(47)

* Little Giant Geyser - 3'+ minors in 1987 & 1988; at least one 20'+ eruption in 1991.
^ Velvet Spring - boiling minors in 1987; to 20' in 1988; to 3' in 1991.
~ May not have been periodic but perpetual spouters.


ORION GROUP
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44
43
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26
Union Geyser
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4
13
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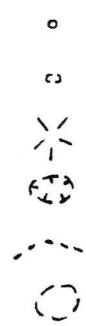
16
17
11
12
14
18
10
9
20
19
21
22
CAMP GROUP
Geyser
Cone
8
Shoshone Creek
23
24
25
trail
N
100 ft

ORION GROUP

Map #	Name	Peale	USGS	Bryan	Function	Notes	Name Source
1	Red Sulphur Spring	32	112		MP/SV	dry in later years	[Peale 1883]
						aka "Wash Tub"	[Bechler 1872]
2		--	111		MP/SV	dry in later years	
3		--	-		S	seep	
4	"Bank Cone"	--	-		S	7+ vents	[Martinez 1976]
5		--	-		S	2 vents	
6	**Taurus Spring**	Taurus	82	"	G/B	originally Taurus Geyser	[Bradley 1872]
						erupted to 50' in 1959	
7		--	-		MP	3 vents (usually dry)	
8	"Peninsula Spring"	--	-		S	3 vents	[Martinez 1976]
9	**Black Boiler Spring**	22	83		PS	originally Black Boiler	[Peale 1883]
10		--	-		S		
11	**Yellow Boiler Spring**	24	84		G/B	originally Yellow Boiler	[Peale 1883]
12		--	-		SV	2 vents	
13	"Fleur de Lis Spring"	23	85		IS/Bulger/S	designated "Clear Spring" on [Bechler 1872] map	[Hancock, Scott, &Danforth 1965]
14	"Undermine Spring"	--	-		S	palpitates	[Martinez 1976]
15		27	-		S	water at -3 feet	
16	**Kitchen Spring** a	21a	87		G/PS/IS	active as geyser in 1983	[Peale 1883]
	b	21b	87		B		
17		18	88		S		
18		26	-		S	in gravel	
19		--	-		FP		
20	unnamed geyser	19	-		G/PS	can also erupt w/ Union	
21	unnamed geyser	--	-		G	can also erupt w/ Union	
22	unnamed geyser	20	86		G	can also erupt w/ Union	
23	(unnamed geyser ?)	30	115		S/(G?)	two vents	
24		29	-		S	plus 3 minor vents	
25a	unnamed geyser	28	116		G/PS/IS/S	active as geyser in 1976	
b - k		28	116		S	(see diagram #2)	
26	**Impenetrable Spring**	1	89		B		[Bechler 1872]
27	**Union Geyser**	Union G	90	"	G	5 erupting vents	[Bradley 1872]
28		--	-		SV		
29		2	-		SV	deep collapse pit	
30	"Sea Green Pool"	3	91	"	G/S	designated "Clear Spring" on [Bechler 1872] map	[Martinez 1976]
31		3½	-		S	3 vents	
32		--	-		S	2 vents	
33		--	-		SV	collapse	
34	"Covered Spring"	4½	-		Bulger		[Martinez 1976]
35	**White Hot Spring**	4	-	"	G/SP		[Bechler 1872]
36	unnamed geyser	--	-	SHO-3	G/S		
37		--	-		S	collapse	
38	unnamed geyser	--	-		G	new in 1978; erupted from a series of cracks	
39	"Fifty Geyser"	--	-	"	G	poorly defined basin	[Bryan 1986]
40		5b ?	-		SV	2 vents	
41		5a ?	-		S		
42		--	-		SV	hole	
43		7 ?	-		SV		
44	unnamed geyser	6	92	SHO-4	G/S	3 vents	
45		9	-		SV	2 vents	
46	**Moss Crater**	8	93		B	superheated	[Peale 1883]
47	Deep Spring	10	-		S		[Bechler 1872]
48	unnamed geyser	14	95		G/PS	number of spouting vents; small geyser in 1985	
49	**Leather Spring**	25	94		S	may be #50 instead	[Peale 1883]
50		--	94a		PS/S		
51		--	-		S		
52		--	-		S		
53	unnamed geyser	17 ?	96		G/PS		
54	**Marble Cliff Spring**	11	98		S		[Peale 1883]
						aka "**Gray Spring**"	[Bechler 1872]
						aka "The Vault"	[Ankrom 1931]
55	"Pear Pool"	13	97		S/PS		[Martinez 1976]
56		15 ?	-		SV		
57	Sulphur Mud Springs a	31	186 & 187		MP	numerous vents	[Peale 1883]
	b				PS		
	c				PS		
	d				SV	one SV is quite loud	
	e				SV		
	f				S	small & muddy	

S	Spring
PS	Perpetual Spouter
G	Geyser
FP	Frying Pan
MP	Mud Pot
B	Boiling Spring
SV	Steam Vent
IS	Intermittent Spring
"	referred to by name
aka	also known as

Abbreviations Used in Tables



spring or geyser

spring hole (no water)

cone or geyser mound

depression

discharge channel

extent of basin or inner vent

Symbols Used on Maps

History of Union Geyser

Sept 6-7, 1872 Dr. Frank Bradley [1872]

During his first two days visit to the Shoshone Geyser Basin Bradley reported 4 eruptions:

Sept 6	night of arrival - time not noted	
Sept 7	10:28	duration 47 min (including steam phase) height 92 feet
	13:55	duration 56 min height 70 feet
	22:25	eruption heard

...the most important geyser of the basin... has now three vents, standing closely in a row, each of which has built up a small mound, beautifully beaded without and pointed within. The eastern vent has an irregularly-oblong opening, about a foot high, and stands upon the base of about 3 feet by 4. The central mound is about 5 feet in diameter at the base, and about 3 feet high, with a deep central, triangular opening, measuring about 30 inches on a side. The western one is about 1 foot high, on a base of about 20 by 30 inches, with two small openings about 2 or 3 inches in diameter. These stand in the mouth of an old geyser, once probably of great power, though now nearly inactive, of which there remains a deep pool about 8 feet wide by 12 feet long in which the surface of the water during our stay at this camp was about 3 feet below the top [see #26]; but it evidently overflows at times, and it is possible that it still spouts occasionally. It showed no sympathy with the present vents during their eruptions. The sections of the layers constituting the old mound is well shown in the walls of this pit. During eruptions, the west vent spouts a little water, 2 or 3 feet high, for from 1 to 2 minutes, and then yields a moderate flow of steam. Meanwhile the center vent is throwing a powerful jet from 70 to 90 feet into the air, which, after about 5 minutes, gradually gives place to steam, the mingled steam and water giving the highest jets. The east vent, spouting from 10 to 50 feet, throws a solid body of water for about 10 minutes, when the whole supply of water seems to be exhausted, and the rush of steam from all the vents becomes more violent and continues some 40 to 50 minutes longer, gradually declining, however, though with many spasmodic renewals. A small flat opening in the space between the central and western vents gives exit to a little water while the geyser is preparing for an eruption, but takes no part in the eruption itself. We called this Union Geyser, because of its combination of the various forms of geyseric action.

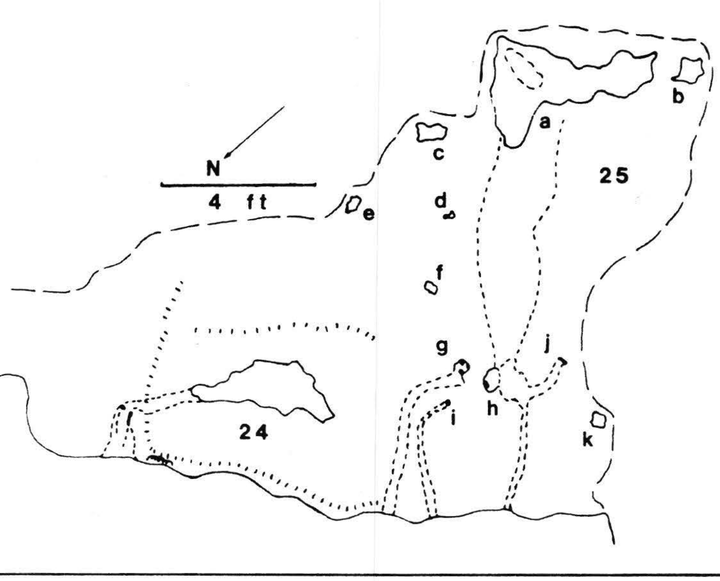


Diagram #2 Orion Group #25

August 14-27, 1878 A. C. Peale [1883]

Union Geyser. --This is the most important geyser in the Shoshone Basin. It has three small mounds or craters close together,... The three craters spout simultaneously, although the smallest one is insignificant in its action.

The central cone is about 3 feet high, and has a circumference of 18 feet at the base. The geyserite composing it is beautifully beaded on the outside, the color grading from yellow to gray, with pearly tints. On top of the cone is a triangular orifice measuring 28 inches on each side. This opens into a globular cavity, which is nearly 5 feet deep and about 3 feet in diameter. This is the outlet of the tube, and soon narrows and becomes crooked, so that we could not get an idea of its depth.

The north cone is next in size, and is about a foot in height. It has an irregular orifice measuring 2½ feet by 1 foot. It soon narrows as we go down. This cone is darker in color than the central one. The south cone is small, having a diameter of about 25 inches, and rising only about a foot above the general level. On the summit are two openings several inches in diameter. Between the central and south cones there is a small hole, from which water flows in the period between eruptions. These cones are situated on a mass of gray and white deposit, which is laminated in its structure, and at places appears to be thin, as it is readily broken through... The eruption begins with a few preliminary puffs of steam, which precede the spouting of the water only a few seconds. The first spurts of water attain a height of 10 to 15 feet. It rapidly rises to 100 feet or more from the central cone. In the small south cone it lasts a few seconds and is followed by steam, which escapes gently, while the other cones are in active eruption. In the central cone the water period [duration] is about 5 minutes, and the north cone 10. Steam follows the water in both, escaping with a steady roar that continues several minutes after the water is exhausted in the north cone. This steady volume of steam changes to puffs at intervals of a few seconds, which gradually diminish until the eruption is ended. So gradual is the diminution that is difficult to say when the eruption ends. The column of water and steam is projected steadily with great force...

Time	Duration(water) C cone	N cone	Duration	Height C	N	Interval
Aug 15						
6:45 pm	5 min	11 min	1:25:00	92′	50′	-
9:35 pm			1:00:00			2:50
Aug 16						
3:40 am						7:05
Aug 21						
7:46 am	5 min	10½ min	1:02:00	114′	56′	5:04:06
10:37 am	8 min	12 min		108′	66′	3:11

Aug 27
We left [the basin]..., and up to that time no eruption... the water is in violent agitation

August 15-16, 1878 Joseph E. Mushbach [1878]

August 15 -- Camp No. 18.

...Our tents are pitched about 50 yards from the main geyser of this basin, called the Union, described by Bradley as being very irregular in its eruptions. He was here in 1872 and we had almost began [sic] to think that it had played out since, when this evening at 6:45 it suddenly began throwing a column of water from the main vent from 80 to 100 feet high. It has three vents in a line almost E [south] and W [north] and about six feet apart. The West [south] one is about one ft. high and the same in diameter, having two openings of about 2 inches each. These spout water a few feet high for a minute or two, and then steam gently for the balance of the eruption to a height of about 10 ft. Next to this is the main vent about 18 inches across, in the top of a mound four feet high and the same diameter[.] This throws the high column of water for 5 or 6 minutes, which then gives place to steam rushing out with tremendous force for about 40 minutes, then gradually dying away in fitful throbs and pulsations for 20 minutes longer. The East [south] vent is about 12 in[ches] wide, in a bound a foot high, and 3 ft wide and acts the same as the main one in the proportion of 50 to 100. Words cannot describe the beauty and grandeur of this sight. We were aroused by a yell from Gannett at 9:40 just as we had dropped asleep and all hands turned out in undress uniform to find that the Union was again spouting, but as it was too cloudy and rainy to see much, we soon turned in again.

August 16--Camp No. 18.

...The Union spouted again at 4 a.m.

August 21--Camp No. 18.

...The Union was in tune today with two fine eruptions, but failed a third one, emitting a little steam only... Spent two hours watching the Union.

July 30-31, 1887 Walter Weed [1887]

July 30

8:04 p.m.	Very fine display from all three vents.
8:08	Middle vent ceased spouting, giving out steam and spray with loud roar.
8:15	North jet ceased spouting.
8:24	End of roaring, but succeeded by gentle emission of steam.
8:30	Gentle steaming entirely over.

July 31

7:20 a.m.	Main cone in eruption 75′; no water from north cone.
7:23	Spasmodic jets from north cone.
7:25	Stream 30′-50′ from north cone; height of main cone now but 50′.
7:29	Main jet declining.
7:30	Main cone commenced steaming, with some spray and steady roar. North cone still playing.
7:35	North cone ceased playing and both vents roar.
7:40	Steaming ceases.
7:41	Steaming commenced again and continues till
7:47	Steaming ceases.
7:48.30	Steaming commenced again and continues till
8:50	Steaming ceases for 30 seconds.
8:54	Steaming ceases for 10 seconds.
9:03	Steaming ceases for 20 seconds.

Oct 1889 Frank Jay Haynes [1889]

Photographs H-1998 & H-1999, Haynes Collection. (According to Allen & Day this eruption was soaped. See (Summer), 1930 Allen & Day below).

Sept 10, 1893 Frederic Remington [1895] [Wister 1958]

On the shores of the Shoshone we camped, and walked over to the famous Union Geysers, which began to boil and sputter, apparently for our especial benefit. In a few minutes two jets of boiling water shot a hundred feet in [the] air, and came down in rain on the other side, while a rainbow formed across it. The roar of the great geysers was awe-inspiring; it was like the exhaust of a thousand locomotives, and Mr. Burgess nudged me and remarked, "Hell's right under here."

(probably) **1897 Mary C. Ludwig** [Whittlesey 1988]

...when we reached the scene, the wonderful concert that greeted us held us spellbound. The leader in the center was throwing a column of water to a height of perhaps 150 feet. Its companion, on the eastern [north] side was not far below it; and the quartet was completed by the two trumpets of the western [south] cone. Art never equaled these musicians.

1911 Jack Haynes [Howe 1911] [Whittlesey 1988]

Jack Haynes saw an eruption of Union in 1911 and secured a photo of it.

(Summer), 1930 Allen & Day [1935]

By soaping this geyser Mr. F. Jay Haynes, former official photographer of the Park, succeeded in bringing on an eruption of which he obtained an excellent photograph. His experiment was successfully repeated by one of the authors as late as 1930. All three cones of the geyser are still very hot, but until this recent test it had not been seen in eruption for a long time.

August 9, 1931 Thomas J. Ankrom [1931]

South of [Taurus is] located three cones of geysers close together, this is the Union Geyser formation; there seems to have been very little action of these during the last few years.

The North and center tubes boil to a height of a few inches above the tubes, but does not go over the sides. The South tube erupts to a height of about eighteen inches, and is the only one that has kept the algae alive.

February, 1934 Frank W. Childs [1934]

<u>Union Geyser</u>. Activity normal. Two eruptions noted this past month. Interval was not recorded as I was not sure that they were consecutive eruptions.

September 3, 1946 William B. Sanborn [1947]

Union Geyser not active as a geyser.

July 23, 1947 William B. Sanborn [1947]

There appears to be an increase in activity on the whole in this basin [over last year]. The Union Geyser cones have much more algae around them, indicating an increase in the amount of water that is splashing out of the cones. All three of the Union cones spasmodically overflowed.

August 19, 1948 William B. Sanborn [1948]

On the afternoon of August 17, 1948, while making thermal observations in the Shoshone Geyser Basin, the major cone of the Union Geyser was found to be damaged.

Inspection revealed that a 'mineral pick', or some similar tool, had been used on the north-east side of the cone. A hole over one foot in diameter had been "hacked" into the cone, water filled the bottom of the opening coming from a vent inside the cone shell itself. Marks of a four sided tool were plainly visible in the sinter bordering the hole, and the pieces so removed from the feature were scattered around the base of the cone. Observation leads me to believe that this was very recent, perhaps not more than a week at the most prior to this visit to the area. Horse evidence, and fresh shoe marks were plentiful in the immediate vicinity of the cone - a campfire had been built just to the southeast of the geyser also.

I erased all evidence of vandalism, including the smoothing out of the pick marks in the opening, scattered the charcoal from the fire, and removed the broken portions of the cone.

(Summer), 1950 Clarence C. Alleman [1950]

Of course, the basin is small and the only large geyser is the Union with its three coordinating cones;...

Union Geyser erupted twice, once at 10 A.M. and again at 2 P.M. on the first day I was in the basin. We heard it again at about 9:45 in the evening after we had gone to bed. From the appearance of the sinter the next morning this must have been the biggest eruption of the three; since the runoff had drained off in all directions--leaving considerable debris as evidence of the activity. There was no eruption at all of the Union on the day following. In the forenoon it was unusually quiet, so I had a good chance to examine the various craters. All of the craters have a part in the eruption but, of course, the large one carries the bulk of the activity. There was a break on the east side of the largest crater, that on first inspection looked as if it might have been the work of vandals. However, later I was convinced that it was a natural development that had proceeded from the inside of the crater. [See August 19, 1948 William B. Sanborn above]. If this particular development continues it will probably alter the present main crater a great deal.

August 4, 1953 David Stevenson & John Albright [1954]

...the fewer tourists who wait out Grand or Giant are inclined to consider their experience as unique. To these self-satisfied visitors we offer Union Geyser in the Shoshone Geyser Basin. This triple-coned affair played for us about 1:00 p.m. on August 4. Of course, it was fortunate that Sam Beal could predict the eruption and thereby have us on the spot.

The eruption was a sight to behold. First, boiling water overflowed in a vaulting billowy manner. Then, jets of water and steam shot up from the center cone to a height of more than one hundred feet. A thin spurt sprayed up about 20 feet from the smallest cone..., and water and steam billowed out of the right cone approximately fifty feet into the air. Gradually, after fifteen minutes of heavy discharge from the center cone and the "baby" cone, the steam phase ensued unabated for another fifteen minutes. It is the noise, however, that makes this geyser unique. The hissing that accompanied the initial overflow turned into a pulsating, throbbing roar which, in turn, was dwarfed by the thundering, pounding, and roaring as the center cone went into its steam stage. Watching silently in awe, we could only compare this to the tremendous roar of a gigantic waterfall. Giant may be higher, Grand may have a more beautiful spray, Old Faithful may be more regular and thereby the most famous, but triple-coned Union Geyser, with her surging overflow and her thunderous steam phase, is certainly a wonderful spectacle.

August 4, 1954 Nat Lacy [1955]

It is reported that Union Geyser erupts "several times a week", but during my stay of several weeks at Shoshone Geyser Basin this geyser was observed in eruption only once. At 5:50 p.m. on the night of August 4, 1954 a roar was heard by me. I was in the cabin at the time and so went to look at the geyser. It was found to be in eruption, and the eruption lasted for fourteen minutes. Water and steam were thrown from the 3 cones to an estimated height of 120 feet, and then the geyser settled down to a steam phase that lasted for 2 hours. During this phase, steam issued forth for periods of 15 minutes, and then would come a quiet period of 2 minutes, followed by more steam of an audible and visible nature.

February-March, 1960 B. Riley McClelland [1960]

Observations at Shoshone Geyser Basin: During the ski trip with District Ranger Elt Davis, March 4 - 6, no signs of recent unusual activity was observed at Shoshone Geyser basin, with the exception that there had been a major eruption of Union Geyser since the ski trip of February 4 - 6 made by Keithley and Peterson.

June 29, 1973 Rick Hutchinson [1973]

11:45	~11 minute water phase	80 - 100 feet
14:46	~13 minute water phase	40 - 60 feet

Union Geyser - This is the tallest, noisiest and most spectacular geyser in the Shoshone thermal basin... Upon arriving on the evening of the 28th it was noted that Union had [been] splashing and overflow[ing] from 2 of its 3 vents. The same activity was seen again on the following morning with no apparent increase. In addition a marker in the runoff channel from the previous night was still in place. Then at 11:45 A.M., with virtually no warning, Union went into a major eruption with all 3 vents. The manner of its beginning is very reminiscent of that from Beehive in the Upper Geyser Basin having a gradual but rapid buildup in height. Estimated maximum height from the central vent was 80-100 feet; from the west [south] vent which shot a very thin but beautiful jet, 10-15 feet, and from the east [north] vent a height of at least 50 feet.

The center vent went into a very noisy steam phase after 4 minutes of play--more noisy than Castle, Beehive, or Lone Star Geysers. It was preceded by about 1 minute by the west vent turning to a forceful pencil thin steam jet and followed by the east vent going into steam phase after a total of 11 minutes of play. The steam phase [lasted] for 20 to 30 seconds at 12:03 and for 5 seconds at 12:24. At 12:28, after 43 minutes from the start of the eruption the roar became intermittent and the steam phase was over for all practical purposes.

At 2:46 P.M. Union had another eruption, only 3 hours and 1 minute from the last. However it was not as powerful as the first as the activity was mainly from the center vent, playing only to a maximum height of 40 to 60 feet. In addition, the east vent played only intermittently 15-20 feet and the small west vent just steamed. The water phase lasted 13 minutes and the steam phase became intermittent 3 minutes later. No more eruptions from Union occurred during the following 24 hours while in the basin.

The fact that Union may have major and "minor" eruptions has been known for some time. Dr. W[illiam] A. Sanborn of Newport Beach, Cal., who has made extensive observations in the Shoshone Geyser basin, reported in a letter to George Marler that he has "a suspicion that this geyser has at least 2 different eruption patterns. One type of eruption actually shakes the ground in the immediate vicinity of the geyser... Another type in (his) opinion, simply does not have the magnitude of the above, to virtually no steam phase. I am reasonably sure that Union is a far more regular performer than suspected."

August 12, 1974 Sam Martinez [1974]

14:15	duration ~7 min continuous steam phase last only a few minutes
17:19:47	center cone water phase starts and lasts almost 6 minutes
17:22:15	north cone water phase starts and lasts almost 8 minutes
17:19:55	south cone starts a loud steam phase (no water)

The eruption was very impressive and powerful. The nearby spring, [#22], erupted all during Union's eruptions to almost 1 foot high. The spring was highly agitated around the edge where the water normally boils up only a few inches. This activity which was also seen last year would indicate connections to Union geyser.

August 8-14, 1976 Scott Bryan [1976]

Aug 8
19:01 eruption (start of active phase)

Aug 13
19:03 eruption (start of next active phase)
maximum height of center vent ~120 feet
duration for center cone ~6 minutes, for north cone, ~10 minutes
duration including steam phase ~45 minutes
10:06 eruption
interval 3hr 3 min

Aug 14
5:43 eruption
interval 7 hr 37 min

Sometime after the initial eruption a large section of sinter fell from the southeast side of the central cone. Though finely beaded on the surface, this section of the cone has long looked very dilapidated, as this was probably a natural occurrence...

August 24, 1976 Sam Martinez [1976]

19:42:50 center cone starts 3:23 duration height ~120'
19:43:12 south cone starts 40 sec duration height ~8'
19:43:27 north cone starts 9:20 duration height ~55'

22:38:39 center cone starts 4:03 duration
22:40:42 north cone starts 8:12 duration south cone steams only

September 5, 1976 Sam Martinez [1976]

8:39 center cone starts ~6 min duration north cone erupts

Note: #22 erupts to 3 feet during eruption of Union

11:38:50 center cone starts 9:15 duration
11:42:27 north cone starts 7:30 duration

Note: #22 erupts to 16 inches

18:40:49 center cone starts 9:51 duration
18:44:00 north cone starts 8:15 duration

Note: #22 erupts to 1½ feet

The pattern this year was different from the past several seasons. The interval [from series to series] increased from 3 to about 5 days. The average number of eruptions increased from 2 to 3...

[Spring #22] ...erupted to as much as 2 to 3½ feet, especially in the early stages of Union's activity...

...the second eruption [of the series] followed the first by about 3 hours. The third eruption, when one occurred, was six or seven hours after the second. All the eruptions after the first started without the overflow from the cones, following a period of steam puffing from all the vents instead. The south cone discharged water only in the first eruption of the series...

The magnitude of all the eruptions is about the same, the height of the north and central columns being only slightly lower in the secondary eruptions... The great pressure with which the water and steam are ejected during the first few minutes makes the ground near the cone[s] pound and vibrate with such violence that one is almost afraid to approach too near for fear the cones will fly apart. It easily outdoes Castle, Beehive, or Lone Star at their best.

...The center cone has a large section missing from the outer thickness on the east side. [See August 19, 1948 William B. Sanborn]. At the bottom of that cavity is a small fissure which sputters when the craters are full... There is another hole in the center cone on the back [west] side just on the top. Since this is only an enlargement in a crack continuing down the side from one corner of the main vent and opens directly into the geyser tube it will not be considered separately. [Other] small vents are located approximately between the center and south cones, two on the east side and three on the west or back side of the platform... Only the southernmost one on the east side is anything more than a seeping hole. When the craters are full it is the first vent to begin discharging. Its flow is slight and amounts to about 0.3 GPM. The north cone is the only other vent which discharges a significant amount during the quiet phase, and its intermittant [sic] flow accounts for about 0.5 GPM.

July, 1978 Sam Martinez [1978]

Union was completely dormant this summer. The temperature was not taken, but... the boiling was less vigorous... Overflow continues...

Union has remained dormant to date (1991). In more recent years the water level in Union has varied from more than 4 feet below overflow to as little as one and a half feet.

CAMP GROUP

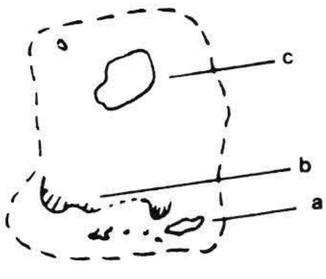
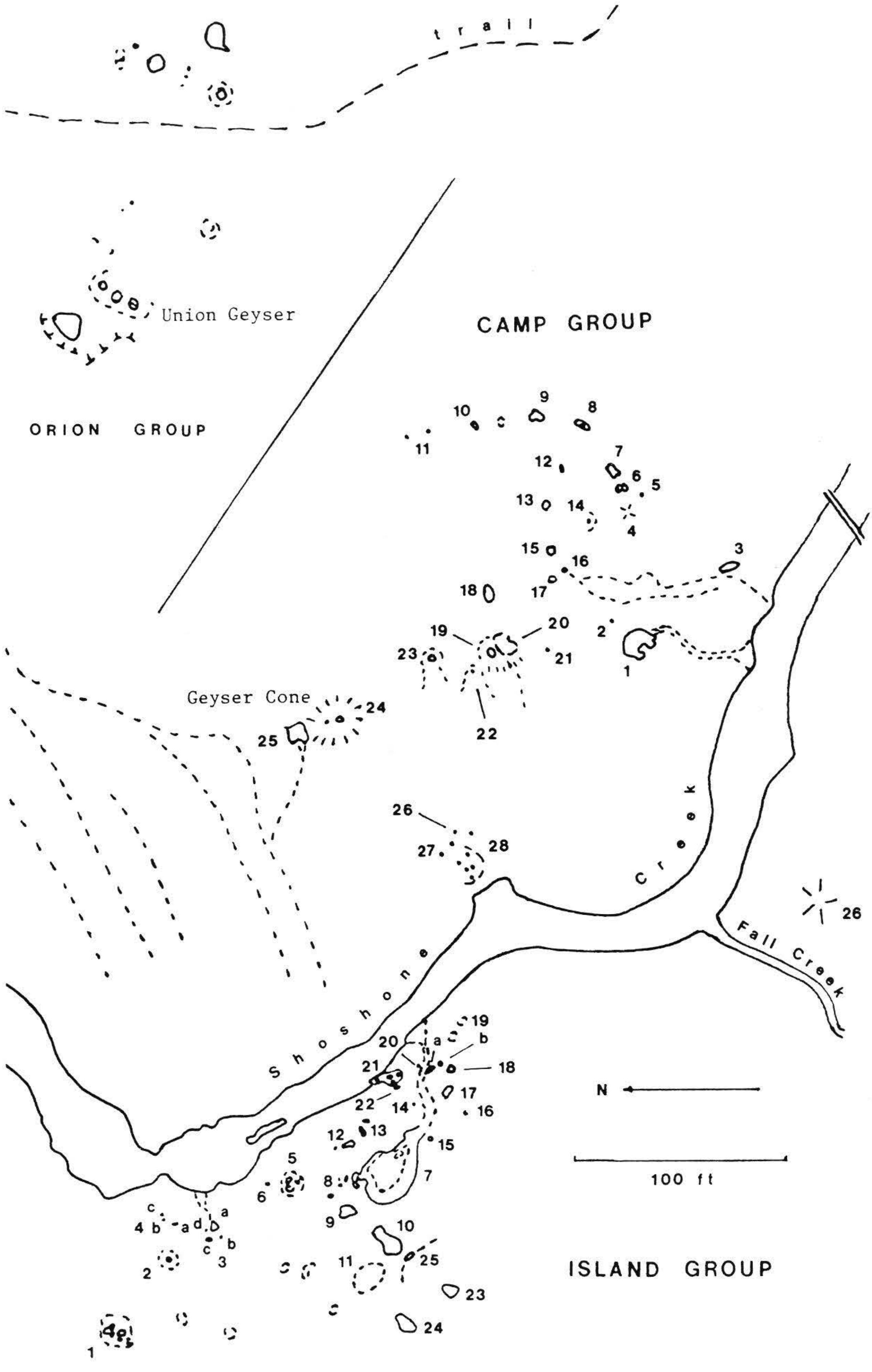


Diagram #3 Camp Group #7


trail
Union Geyser
ORION GROUP
CAMP GROUP
Geyser Cone
Shoshone
Creek
Fall Creek
N
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ISLAND GROUP
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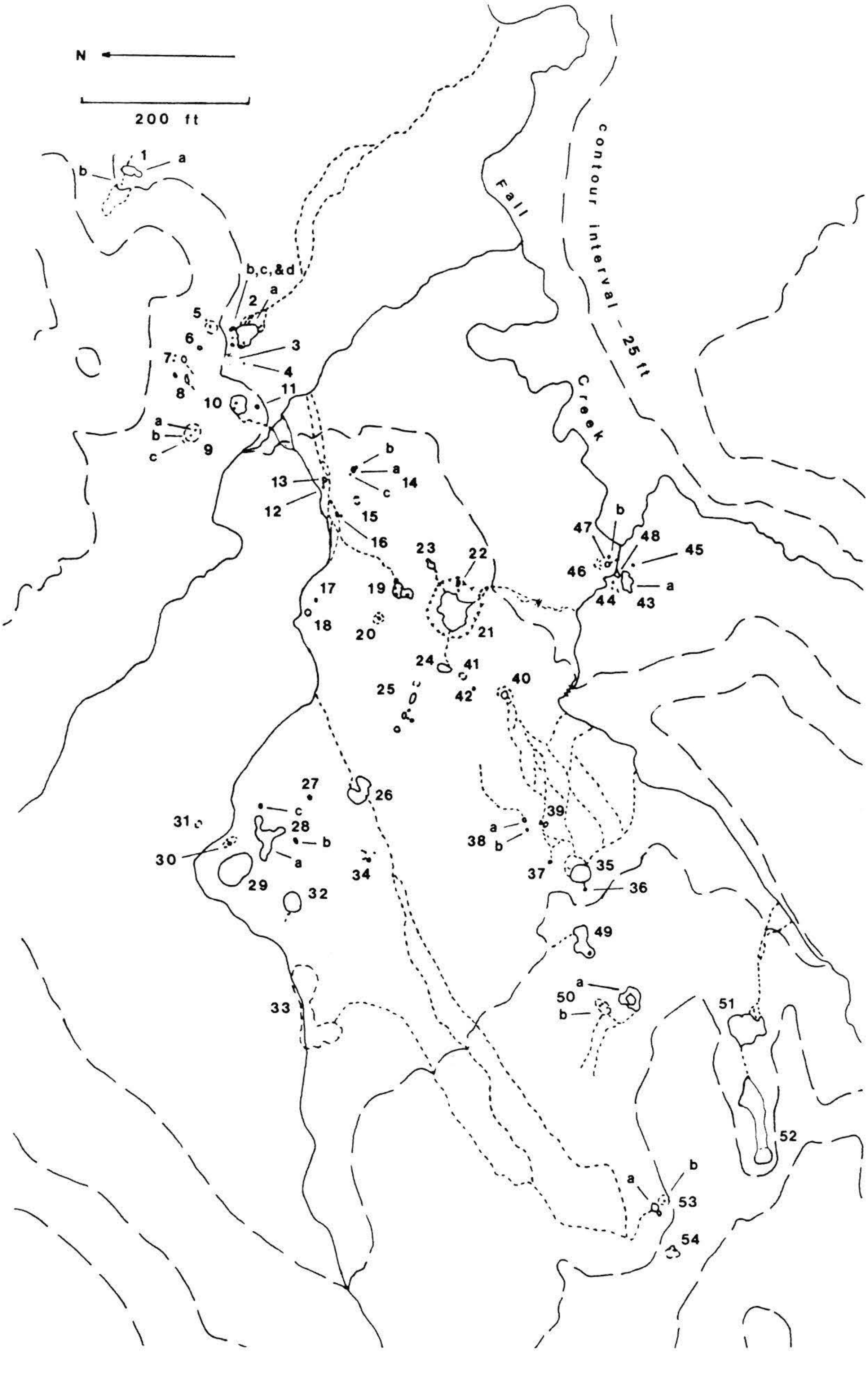
24
25
26
27
28

CAMP GROUP

Map #	Name	Peale	USGS	Bryan	Function	Notes	Name Source
1	**Washtub Spring**	1	121		S	originally "Wash-tub"	[Peale 1883]
2		-	-		SV	small hole	
3		-	-		S	water -1'	
4		-	-		-	sealed off cone	
5		-	-		S	water down 1½'	
6		5 ?	120 ?		S	two vents	
7a	unnamed geyser	-	-		PS/G	active as geyser in 1991 (see Diagram #3)	
b		-	-		S	along fracture	
c		-	-		S		
8		-	-		SV/S		
9		7 ?	-		PS	spouting vent new ~1982	
10		-	-		SV		
11		-	-		MP	2 small holes	
12		-	-		S		
13	**Lavender Spring**	4	-		MP		[Peale 1883]
14		-	-		SV	decayed spring	
15		3	119		PS	cyclic	
16	unnamed geyser	-	-		S/G/PS	geyser in 1987 & 1988	
17		-	-		S		
18		2	118		S		
19		-	117 ?		S		
20	"Elk Hoof Spring[s]"	-	-		S/PS	numerous sputtering holes	[Martinez 1976]
21		-	-		SV		
22		-	-		S/PS	now decaying	
23		-	-		PS	12+ beaded vents	
24	Geyser Cone	6	-		G/S	rejuvenated in ~1974	[Peale 1883]
25	unnamed geyser	(6)	-		G/S	geyser in 1989 & 1991	
26		-	-		S		
27		-	-		SV	3 collapse holes	
28		-	-		S	5 muddy vents	

ISLAND GROUP

Map #	Name	Peale	USGS	Bryan	Function	Notes	Name Source
1		9	122		S/PS	PS from 2 vents when active	
2		-	-		S		
3a		7	123		S		
b		-	-		S	cone	
c		-	-		S		
d		-	-		S	small hole	
4a		8a	-			cone (now disintegrating)	
b	(unnamed geyser ?)	8b	-		SP/(G ?)	cone	
c		8c	-			double cone	
5		6	124		S		
6		-	-		SV		
7	(unnamed geyser ?)	3	126		SP/B/(G ?)	vent within may be a geyser	
8		-	-		S	4 small springs	
9		4	128		PS/B		
10		5	127		S		
11		-	-		S	mostly dry	
12		2	125		S/PS	with small vent to N	
13		-	-		S	2 vents	
14		-	-		S		
15		-	-		S		
16		-	-		S	bubbler	
17		-	-		S	muddy spring	
18		-	129		S	muddy spring	
19a		-	-		S		
b		-	-		FP		
20		-	-		S		
21a		1	-		PS/S	(see Diagram #4)	
b		1	-		S		
c		1	-		S	receives water from #21d	
d		-	-		-	underground discharge	
e		-	-		-	underground discharge	
22		-	-		S		
23		-	130		S	light mud bottom	
24		-	131		S	muddy spring	
25		-	-		SV	from under sinter ledge	
26		-	-		-	dead cone	


N
200 ft
contour interval - 25 ft
Fall Creek
1 a b
2 a b,c,&d
3
4
5
6
7
8
9 a b c
10
11
12
13
14 a b c
15
16
17
18
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21
22
23
24
25
26
27
28 a b c
29
30
31
32
33
34
35
36
37
38 a b
39
40
41
42
43 a
44
45
46
47 b
48
49
50 a b
51
52
53 a b
54

WESTERN GROUP

Map #	Name	Peale	USGS	Bryan	Function	Notes	Name Source
1a	Black Pool	43	-		S		[Peale 1883]
b		-	-		S	spring below area of seeps	
2a		1	132		PS		
b		-	-		S		
c		-	-		S		
d		-	-		S		
3		-	-		S	area with 7 small vents	
						(see Diagram #5)	
4		-	-		S	small hole	
5		2 ?	-		S	number of small muddy	
						springs; 2 largest shown	
6		7 ?	-		S	water under ledge	
7		6 ?	-		MP	very active; 2 SV's to N	
8		5 ?	-		S	large SV to N	
9	Red Spring a	4	134		PS/G	active as geyser mid 80's	[Peale 1833]
	b	4	134		S/G	active as geyser in 1982	
	c	-	134		SV	new vent in 1978	
10		3	133		S		
11		-	-		S	dying spring	
12		13	-		G	new as geyser in 1987	
13		14	135		S	receives water from #12	
14a	"Pectin Geyser"	21	136	SHO-9	G	also with a crack vent	[Martinez 1976]
b		-	-		S	vent on same fracture	
c		-	-		SV	small hole	
15		-	-		-	dead moss covered spring	
16a	unnamed geyser	-	137 ?		PS/G	active as geyser in 1991	
b		-	137 ?		PS	(see Diagram #6)	
c		-	137 ?		PS		
d		-	137 ?		S		
e		-	137 ?		PS		
f		-	137 ?		PS		
g	unnamed geyser	-	-		G	new in 1991 ?	
17		12	-		S		
18		11	-		S		
19	Boiling Cauldron a	8	139	"	PS		[Peale 1883]
	b	9	139		PS	many spouting vents	
20		10	140		PS		
21	Great Crater	17	142		S		[Peale 1883]
						aka "Grand Boiling Spring"	[Bechler 1872]
22		-	-		PS	near E edge of #21	
23		16	141		S		
24	Cream Spring	18	143		S		[Peale 1883]
25	Mud Pots	36	144		MP	7 spring holes	
26	"Double Crater Spring"	37	145		S		[Martinez 1976]
27		40	-		PS	reactivated in 1978	
28a	Muddy Pool	41	148		S		[Peale 1883]
b		-	-		S		
c		-	-		S		
29		(41)	-		S	reddish pool in grass	
30	Red Pool	42	150		S	bubbling vent	[Peale 1883]
31		-	149		-	dead mound	
32		39	147		S	deep pool in grass	
33		-	-		S	extensive area of seeps	
34	Nursery Springs a	38	146		S/B	(see Diagram #7)	[Peale 1883]
	b	38	146		S/PS		
	c	38	146		S		
	d	38	146		bubbler/PS	with tiny side vent	
	e	38	146		S/PS		
35	Moss Basin	29	152		S		[Peale 1883]
36		32 ?	-		S	in area of seeps	
37		30	-		S	small hole	
38a		31a ?	-		S		
b		31b ?	-		S		
39		28 ?	151		S	now 2 dying springs	
40		(27)	-		S	sink	
41		26	-		S	no water	
42		-	-		S		
43a		23	-		S	heated up in 1991	
b		-	-		-	outlet for #43a	

WESTERN GROUP (Continued)

Map #	Name	Peale	USGS	Bryan	Function	Notes	Name Source
44		-	-		S	3 new collapse vents	
45		24 ?	-		MP	cool mud hole	
46		19 ?	-		-	dead mound w/collapse	
47		-	-		S	good discharge	
48		-	-		S	almost dead	
49		34	153		S	rejuvenated in 1988	
50a		-	-		S	deep muddy pool; new & overflowing in 1988; -5'in '91	
b		-	-		MP/SV	also overflow basin for #50a	
51	Boiling Spring	33	156		PS/S	near dormant in 1988; some rejuvenation by 1991 aka "Grand Boiling Basin"	[Peale 1883] [Bechler 1872]
52		-	155		S		
53a	Steam Vent (Spring)	35	154		S		[Peale 1883]
b		(35)	-		SV/S	active as a spring in 1991	
54		-	-		PS/G	new in 1988; sub geyser in 1991	

ISLAND GROUP

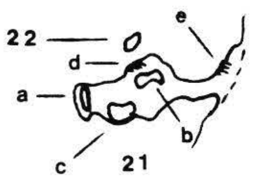


Diagram #4 Island Group #21

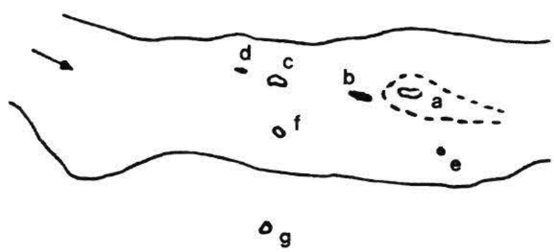


Diagram #6 Western Group #16

WESTERN GROUP

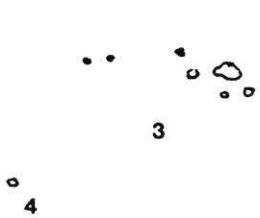
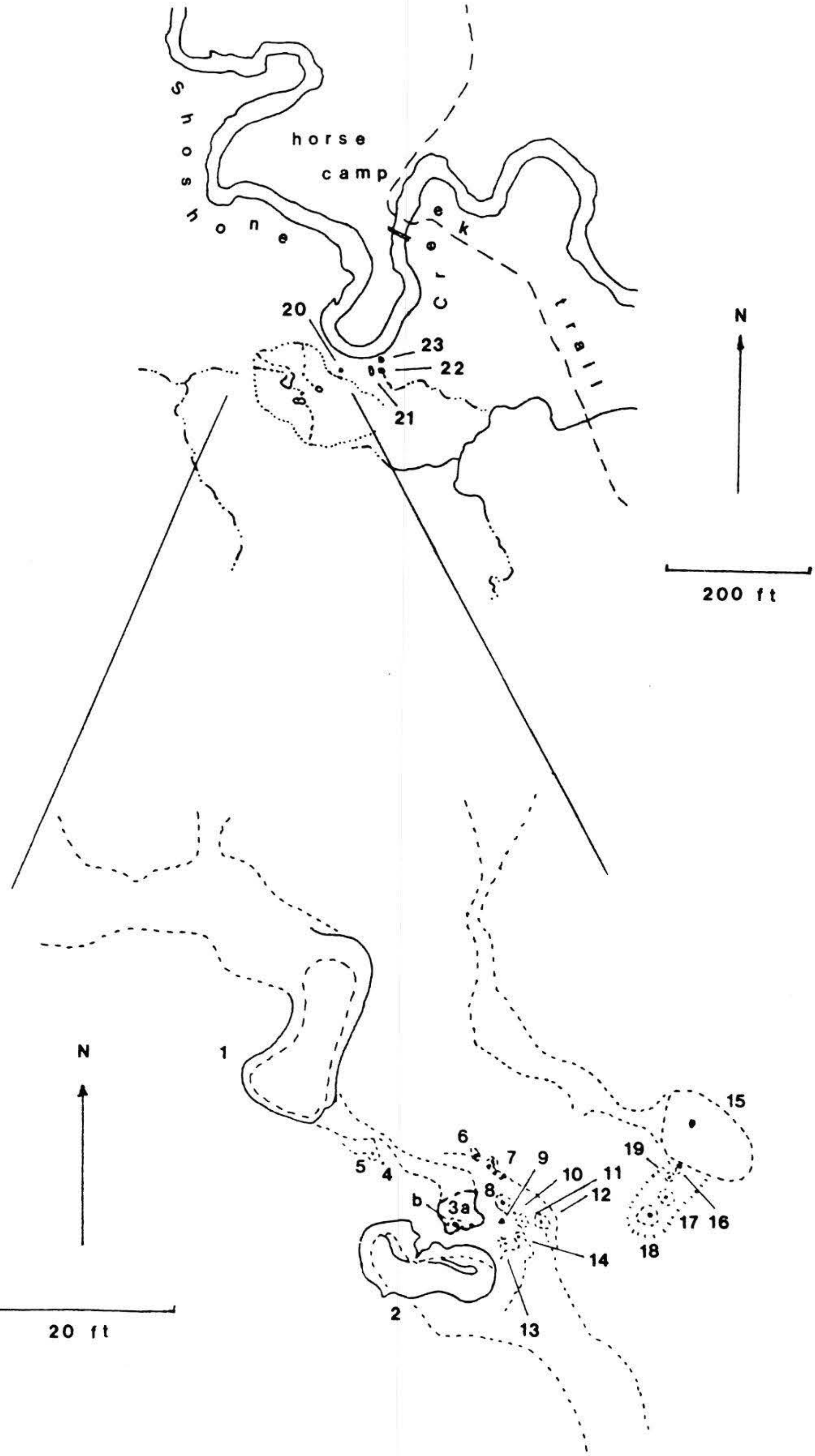


Diagram #5 Western Group #3

Diagram #7 Western Group Nursery Springs

"HORSE CAMP GROUP"



"HORSE CAMP GROUP"

Map #	Name	Peale	USGS	Bryan	Function	Notes	Name Source
1		-	161		S	large opaque blue pool	
2	"Double Vent Geyser"	-	160		PS/G	long overhung vent within	[Martinez 1978]
3a		-	-		S	discharge vent for #2	
b		-	-		S	tiny vent on sinter rim	
4		-	-		S		
5		-	-		S		
6		-	-		S	4 connected vents	
7		-	-		S		
8		-	-		S		
9		-	-		S		
10		-	-		S		
11		-	-		S		
12		-	-		S		
13		-	-		S	tiny cone	
14		-	-		S		
15	unnamed geyser	-	162		G	to 2' when active	
16		-	-		S		
17		-	-		S		
18		-	-		S		
19		-	-		S		
20		-	-		S	small vent in grass	
21		-	163		S	with red algae	
22		-	164		S	2 vents with 3rd along channel	
23		-	165		S	deep, cool, and muddy	

ADDITIONAL NOTES

Little Giant & Taurus Geysers

For quite some time I thought it to be a commonly held belief that Little Giant Geyser has had no "major" activity for decades if not for all of this century. But a couple items have recently come to my attention that would tend to dispute this.

Park naturalist, Al Mebane [1959], in his "Summary Report of My Activities and Findings for the Earthquake Study, 1959" dated December 18, 1959, stated the following:

> 12. Shoshone Geyser Basin
>
> The general thermal activity here seems to be somewhat intensified. Taurus Geyser now erupts to about 50 ft., its heavy discharge eroding the soil and sinter around the vent. Little Giant Geyser plays more frequently than before the quake. Bronze Geyser, which played every 2 minutes in July, 1959, was inactive during our visit.

There are a few noteworthy items iterated above. Taurus Geyser to 50 feet! That Al Mebane is talking about the real Little Giant Geyser can be vouched for by a photograph of Little Giant in eruption taken by McIntyre on October 3, 1959. (Probably in the basin with Al Mebane). This photo is quite clear and shows Little Giant erupting to about 15'- 20'. Also noteworthy is the statement that Little Giant "plays more frequently than before the quake" implying that it was known to be active recently before the '59 quake.

In 1976 Scott Bryan noted one minor eruption of Little Giant Geyser to 6 feet. But in October of just last year (1991) I discovered very recent evidence (not there a few weeks before) of what must be considered a "major" eruption. Considerable runoff had covered the basin in the immediate vicinity of Little Giant's main opening, and <u>very</u> heavy runoff had traveled down its long unused runoff channel toward Shoshone Creek. It washed out much of the debris and killed a lot of grass!

Large Pool Across Shoshone Creek from Minute Man

Another item of some interest in the Shoshone Geyser Basin is the large "Blowout Pool" [Ashley & McClelland 1965] across the creek from Minute Man Geyser. In a 1986 report, Scott Bryan wrote the following about this pool: "Huge, deep pool on the SW side of the trail, evidently formed during 1920's; previously mistaken by me for Funnel Spring." The following excerpts are taken from an article in the July, 1930 issue of the <u>Yellowstone Nature Notes</u> by Charles C. Davis:

> New Pool Near Shoshone Snow Shoe Cabin
>
> Last year... I discovered a new pool which had been formed between that time and the time of my first observation [in 1929] by blowing an opening in the ground fifteen feet in diameter... It has a great depth and evidently came into existence by a terrific explosion... through the soft and disintegrating shale-like geyserite material of that location. Large lumps of soft greyish material were blown... even sixty feet away... There is not as much action in the pool now [1930] as there was last season. This is due to the appearance of a new spring which came into action sometime during last winter. This spring plays continuously throwing heavy columns of water several feet into the air.
>
> The water from both the pool and the spring is very clear... The walls of the pool are soft and crumbly and are not coated by any kind of deposit.

The Dueling "Lions"

In Peale's 1878 report [Peale 1883], there is a geyser in the North Group named Lion Geyser. The map of the Shoshone Geyser Basin, included in Peale's report, shows "21 Lion Geyser" associated with the southernmost of 3 vents (or springs) which generally lie in a north-south alignment. Peale's description of "21 Lion Geyser" is presented in both the Table of the North Group plus in the main text. They are as follows:

Table:

> 21 Lion Geyser... 17 by 17 feet... There are two openings separated by flaky deposit; openings are about 2 feet diameter.

Text:

> No. 21 Lion Geyser.-- This is a small spouter in a basin measuring 17 by 17 feet. The orifice of the spouter is about 2 feet in diameter. There is another opening of about the same size. The water is spurted diagonally to a considerable height from beneath a flaky deposit.

Although the above description and manner of eruption is like that of the feature we are today calling "Lion Geyser", there are definite problems with the placement of Peale's "Lion Geyser". Over the past couple decades, the erupting feature has been the northernmost of these same 3 vents. In 1982 all that was discernable of the southernmost vent was a small depression of about 2 to 3 feet in diameter; it was completely covered by a long standing sinter deposit. A runoff channel from above was flowing over this area until a couple years ago and continued to add additional deposit. By 1989, this southernmost vent was almost obliterated. A second problem concerning the placement of Peale's "Lion Geyser" was the fact that it erupted from one of 2 vents positioned within a 17' by 17' basin. As seen in 1982, only the two southernmost vents of these 3 could fit this criterion. These two vents are about 12 to 15 feet apart, while the middle vent and the northernmost vent are well over 20 feet apart. (It is this northernmost vent which is being called "Lion Geyser" today). Again it would seem that Peale's "Lion Geyser" had to be this southernmost of the 3 vents.

A few years ago I obtained from Lee Whittlesey Walter Weed's 1887 notes on the Shoshone Geyser Basin. Herein were 26 pages on this basin but they only seemed to confirm the above conclusion. Weed wrote:

> 21 Lion Geyser
>
> Vent of spouter. 3" diam[eter] as seen from top; lining of light creamy yellow sinter.
> North vent is simply a sink hole and is lined with leathery algous material.
> The deposit of the Lion is a light tan colored sinter,... and there is a little marginal deposit, and isolated fungoid masses...
>
> Hole in slope, back of Lion, 6" -10" X 15". Slightly turbid water boils vigorously; no overflow and no deposit.

Now a third problem appears; namely, the " 3" diam[eter vent] as seen from the top". This would not seem to fit today's Lion Geyser. In fact, the dimensions of Weed's "Hole in slope" would more closely describe it. (Weed's "North vent" would be describing the central vent of the three).

In the article I submitted for the 1989 GOSA Transactions (Vol I), I was not satisfied with the placement of "Lion Geyser" and wrote in the "Notes" column "May not be original Lion".

Finally, sometime from mid to late Summer of this past year (1991), the southernmost of these 3 vents blew out most of its sinter overlay revealing an old vent. A large portion of smooth, brick-red sinter lay exposed within this "new" basin, clearly indicating this was a re-exposure of an old feature. A tan to cream colored deposit was already starting to cover up this brick-red deposit. In addition, as seen from above, this "new" vent was seen to quickly narrow to ~3" in diameter! And further, from the angle in which the vent was seen to descend, it appeared that it would also erupt at a considerable angle. This "new" vent erupted erratically over the next few months, as attested to by a new runoff channel and moved markers. Unfortunately, even after 3 long visits to the basin I had not yet seen it in action. In spite of being fairly sure that this was indeed Peale's "Lion Geyser", I wanted to see an eruption to be convinced.

On October 13, 1991, I got to see an eruption. Based on previous examinations, I became convinced that this "system of 2 geysers", namely, the traditional Lion Geyser and this "new" vent, was erupting on an interval of about 5 to 6 hours, with sole play from Lion greatly predominating. In other words, most of the time today's Lion Geyser would erupt and only occasionally would the "new" vent erupt. At 18:45 on the 13th, today's Lion Geyser began to erupt. About 30 seconds later the "new" vent also began to boil up and spout. Within another half minute both geysers were erupting in tandem! What made the spectacle even more fascinating was what was happening during most of the pulses. As it happens, today's Lion Geyser erupts at about a 40° angle to the south to a distance of more than 25'. On the other hand, this "new" geyser also erupts at an angle, about 45° to the east-northeast. During most of the pulses, the water from these two vents collided! Thus we have the dueling Lions!

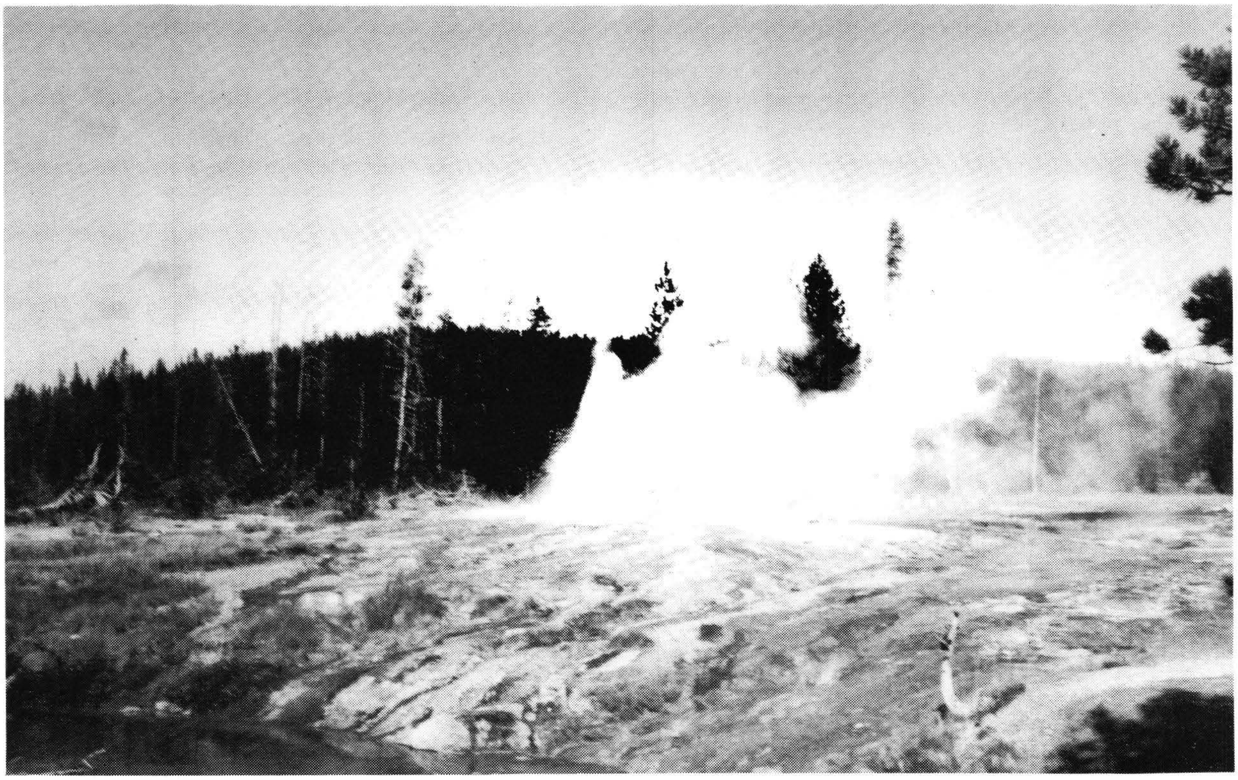
Conclusion:

I now am convinced that the correct placement of Peale's "Lion Geyser" should be on this "new" vent. The geyser which we have been calling "Lion" is actually an "unnamed" feature. However, the present placement of the name "Lion Geyser" has long been firmly entrenched both in the literature and in our minds. Perhaps I could suggest the following:

1) The northernmost vent, the one traditionally labeled "Lion Geyser" for the past number of years, could retain the name of **Lion Geyser;** and

2) This newly uncovered vent, the southernmost of the 3, could be given the name of **Old Lion Geyser.**

Precedent for this type of action has occurred with the placement of the names of Tardy and Old Tardy Geysers in the Upper Geyser Basin.



Little Giant Geyser Shoshone Geyser Basin Oct 10, 1959 McIntyre YNP Photo Archives

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On the Modern Identity of Three Historic Hot Spring Names

Heart Lake Geyser Basin, Yellowstone National Park

by T. Scott Bryan

Abstract

Modern authors have attempted to correlate Comstock's [1873] Puffing Spring, Sand Spring and Hissing Spring with modern features within the Fissure Group of the Heart Lake Geyser Basin. I believe these correlations to be incorrect, and that a more careful analysis of Comstock's admittedly brief description of these features places them within the Upper Group of the Heart Lake Geyser Basin.

Introduction

The following dissertation might be a pointless exercise. Certainly, it is ultimately a futile one; unless we locate unknown (and almost certainly non-existent) original documents from the early 1870s, answers to this riddle will never be known with certainty.

However, some recent authors have attempted to correlate names given by Comstock [1873] during a cursory 1873 survey with modern features within the Fissure Group of the Heart Lake Geyser Basin. The matter is of some importance because of the features, Hissing Spring was a significant geyser which has now been correlated with Glade Geyser, the tallest at Heart Lake. I believe these decisions to be incorrect.

The features— Puffing Spring, Sand Spring and Hissing Spring— certainly must be located somewhere within the upper portion of the Heart Lake Geyser Basin; e.g., within either the Fissure or Upper Groups. Comstock's description leaves much to be desired, but I believe a careful analysis of it will show these hot springs to lie mostly (if not entirely) within the Upper Group rather than the Fissure Group.

In the following, I first proceed step-by-step through Comstock's descriptions of the three springs, noting problems as I go along. Then I produce my interpretation of the descriptions and give four presumptive conclusions.

Comstock's Descriptions and Their Problems

Comstock [1873] named the three springs during the course of a very brief survey through the Heart Lake Geyser Basin. He noted that his party viewed the springs from the hillside above them, and since no other individual springs besides these were described, there is clearly very little to go by.

To determine the identity of Hissing Spring demands first the correct identification of Puffing Spring, which in turn is partly described by its position with respect to Sand Spring. Even as early as 1878, Peale found it difficult to correlate Comstock's names with Heart Lake features. He somehow presumed that Puffing Spring corresponded to the modern feature described by several modern authors: Paperiello [1989] Fissure Group #126a (hereinafter, F#126a); White [1973] Fissure Group #S20; Bryan [1986] UNNG-HLF-S20. For the most part, the later writers (including myself) have largely accepted Peale's decisions as correct; Whittlesey [1988] lists Puffing Spring as Peale's #20 and Sand Spring as Peale's #23. It was Peale's decisions of more than a century ago that led us more recently to incorrectly "accept" that Hissing Spring is the same as Glade Geyser.

For modern authors to have correlated Peale's version of Hissing Spring with the modern Glade Geyser must be in error. In no way does Glade remotely resemble Peale's "Hissing Spring"; to wit, "#33, 6 by 7 feet, bulger constantly agitated, throwing water 2 feet, at intervals of a few seconds." Glade erupts from a small cone not associated with any pool, and has never been known as a frequent "bulger."

Take some of Comstock's original description:

> "...[Puffing Spring] is situated on a kind of a platform, upon the right bank of the stream, below the main fall, but near the side of a rambling cascade."

This part of the description quite well matches the site of F#126a. It is near the edge of a sloping geyserite shield ("platform"), on the southwest side of the stream (the "right" side when looking downstream), and only a short distance below the main fall of Witch Creek where it cuts the higher geyserite mound which is capped by the fissure that gave the group its name.

However, Comstock continued with:

> "...the vapor... issues from the solid rock."

Here there is no mention of any sort of (geyserite) cone. F#126a not only has a cone, but is notable because the cone is one of the largest in the entire Heart Lake Geyser Basin. Worse, Comstock prefaces the individual descriptions by noting both Puffing Spring and Sand Spring as "bowls." There is nothing bowl-like about F#126a.

The identity becomes even worse with:

> "... The resonance of the escaping vapor is increased with the production of a slight echoing sound, by the wall of the gorge, which partially encloses the spot, somewhat after the manner of an amphitheater."

The site of F#126a is not enclosed at all; indeed, it is set well away from the hillside.

Finally, Comstock notes:

> "...the deposits are largely siliceous, with a fair proportion of iron and some sulphur. Alumina is abundant in several larger bowls lying on an alluvial flat at a lower level."

In no way does such a chemistry fit F#126a. Note, however, that this, the amphitheater-like aspect, and several other points could easily apply to features further upstream, within the Upper Group of springs.

My conclusion then is that Puffing Spring has been misidentified and misplaced since 1878, and that the other named springs have also been incorrectly placed as a result.

Comstock continued his description with Sand Spring. The exploring party was:

> "...camped in a sheltered spot near the brink of a high fall... Just above the falls, nearly opposite our camp, there is a depression in the bank of the creek, but a little above the present level of the stream..."

If the camp was at the upper end of the Fissure Group, where there is the only significant ("high") fall within that group, then the modern identification of Sand Spring is obviously wrong. Some other aspects of Comstock's continuing description do fit with this location, but glaring is the fact that the modern all place Sand Spring downstream from Puffing Spring, yet Comstock has just the opposite: Puffing Spring below and Sand Spring above the falls.

This carries us to Hissing Spring. It has been correlated with the modern Glade Geyser, which lies within the central portion of the Fissure Group. There are several reasons why this cannot be so. Comstock again; descriptive points emphasized will be discussed further:

> "Just after reaching the basin in which these springs are located, a **large spring** at some distance **down** the creek suddenly ejected a dense mass of white vapor to a height of perhaps twenty-five feet, with a **rushing noise** which startled us all. This may have been a veritable geyser, but we were unable to detect any signs of a column of water from our point of view **below** the Puffing Spring, **one hundred rods** distant. The eruption lasted for about five minutes..."

Glade Geyser is not "a large spring." It does occupy a fairly large alcove, but Glade itself is a rather small feature, erupting from a cone with an orifice only about ten inches in diameter.

Comstock's Hissing Spring was some distance "down" the creek, and he further notes a distance of "one hundred rods", or therefore 1,650 feet. Although the use of the rod is nearly obsolete today, it was commonly used during the 1800s.

Whether Comstock meant that Hissing Spring was 100 rods from Puffing Spring *or* that it was 100 rods from his position already an unspecified distance downstream really doesn't matter. A distance of 1,650 feet downstream from what others have accepted as Puffing Spring (that is, from F#126a) places the site for Hissing Spring well beyond the southeastern limit of the Fissure Group. This is patently impossible.

In fact, though, it is highly likely that Comstock did not really mean 100 "rods" as the distance. Consider his eruption; it is hardly possible that Comstock's geyser, while ejecting a vapor cloud only 25 feet high, produced a rushing noise startlingly loud at a distance of 1,650 feet.

Simply put, then, the descriptions of Comstock's springs cannot be rectified with any positions for any of them within the Fissure Group. They can, however, fit with positions within the Upper Group, and actually fit exceedingly well if Comstock's distance is taken as 650 feet.

My Interpretations

In the upper portion of the Upper Group the valley (or here, more like a canyon) of Witch Creek abruptly narrows. Just upstream from Spike Geyser is a narrow gorge which contains falls. Above them is a group of acidic springs. This is the only significant portion of the entire Heart Lake Geyser Basin where springs with muddy/sandy bottoms exist near the stream. I believe that it is only here, fittingly above the falls, where Sand Spring might exist.

Comstock noted a...

> "...thick matting of turf" in the area surrounding Sand Spring. He wrote: "Unconscious of the trecherous nature of the subsoil, of which no indications are visible, I incautiously sprang across the creek upon the flat, when I immediately sank nearly to the middle in a hot quagmire..."

Such does not exist *per se* among these acid springs. But Sam Martinez, in a report dated August 22, 1976, described the area near Paperiello's [1987] Upper Group #34 as follows:

> "The ground approaching and surrounding [these springs] is quite trecherous... the unwary traveller can find himself up to his knees in burning hot mud before he knows it."

Note the strong similarities between these disparate descriptions.

Below Sand Spring, and below the falls (as is necessary), is Spike Geyser and a number of nearby springs. Most of the features of this small cluster lie across the stream from Spike on the right bank of Witch Creek (as is also necessary to the location of Puffing Spring). The single most notable spring here is Paperiello's [1989] Upper Group #27, appropriately named by White [1973] as "Yellow Funnel Spring." This location fits that of Puffing Spring to a tee: it is a bowl on a platform within a distinct amphitheater-like area. A short distance below these springs is a large alluvial flat. Boggy and of difficult access, it contains a few fairly large, low temperature acid springs which have formed efflorescences of aluminum-sulfate salts among their deposits.

Thus, in my mind there can be no question but that Puffing Spring is Yellow Funnel Spring or one of its associated "steaming holes", and that Sand Spring must be one of the muddy features a short distance upstream.

This finally brings us to the identity of Hissing Spring— and some problems. Hissing Spring was, as noted, 100 rods downstream from some point of view below Puffing Spring. Here I was able to generate four presumptive possibilities for its correct location.

Presumption #1— If Comstock's stated distance (100 rods) is correct, and if Puffing Spring is indeed in the Yellow Crater vicinity, then Hissing Spring would lie near the upper limit of the Fissure Group. With this it is after all barely possible that Hissing Spring is in fact a Fissure Group feature. But this is only a vague possibility. Because of the topography, none of the Fissure Group springs is truely visible from any point within the Upper Group, and to sight a dense vapor cloud 25 feet high would be difficult at best.

Presumption #2— This has already been addressed and rejected. If Puffing Spring and Sand Spring are indeed **any**where within the Fissure Group, then the distance of 100 rods downstream would place Hissing Spring well beyond the lower limits of the Fissure Group, and invisibly beyond topography and forest. However, even if a distance correction is made,the described spring positions do not match the Fissure Group.

Presumption #3— Comstock told us that Hissing Spring was "a large spring." Among the largest springs within the entire Heart Lake Geyser Basin is Deluge Geyser, in the Upper Group. Although it has functioned as little more than an intermittent spring in recent years, Deluge is a geyser and historically was once significant. Peale [1878] lists its height as up to 10 to 15 feet.

In a number of ways (here and elsewhere), Comstock appears to have been less than an especially astute reporter. Perhaps he made a rather simple typographic error or two. [Such can happen to anybody. In my own writings [Bryan, 1979, with revised printings] about the Lower Geyser Basin (River Group and Sentinel Meadows) I made two glaring descriptive errors which placed geysers in impossible locations; both were caused by simple, uncaught typographical errors.] Thus, if in fact Hissing Spring was 650 feet rather than 1,650 feet from Puffing Spring, then there would be an almost perfect fit to the world. The true distance from Yellow Funnel Spring to Deluge Geyser is close to 650 feet. Again, this conclusion is supported by the rushing noise loud enough to have startled everybody in Comstock's party; at least, the eruption might have been heard at such a distance.

Although this presumption requires considerable "fudging", I believe it is by far the most realistic.

Presumption #4— None of the above are correct. It is possible that Comstock's descriptions were themselves edited to some extent, leaving out details that would otherwise make these identifications straight-foreward rather than impossible.

Conclusion

For whatever value it may have, I conclude that Puffing Spring, Sand Spring and Hissing Spring all lie within the Upper Group of the Heart Lake Geyser Basin.

This exercise, then, has been just that: a mental exercise developed out of curiosity. Has it been worthwhile? As I said in the Introduction, the true answer to this riddle will probably never be known. Perhaps to seek the answers is completely pointless. After all, although the modern name correlations have been attempted, none of Comstock's names were ever officially approved. If nothing else, it has been fun!

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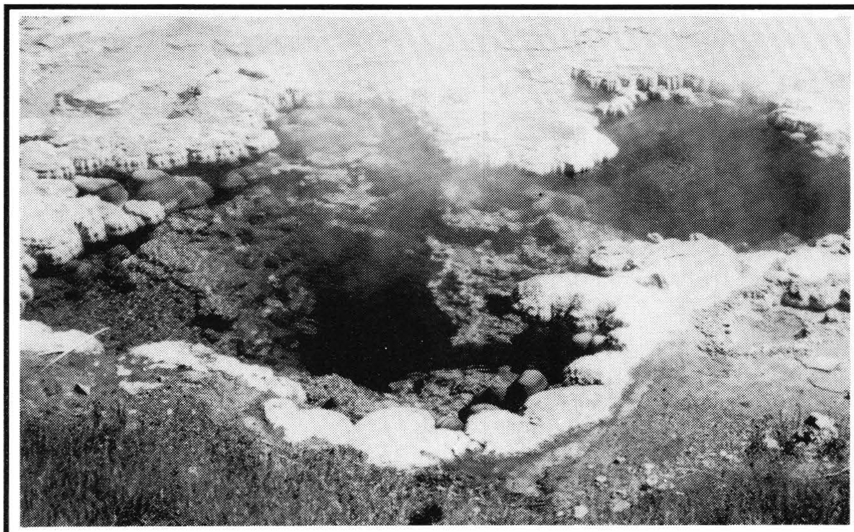
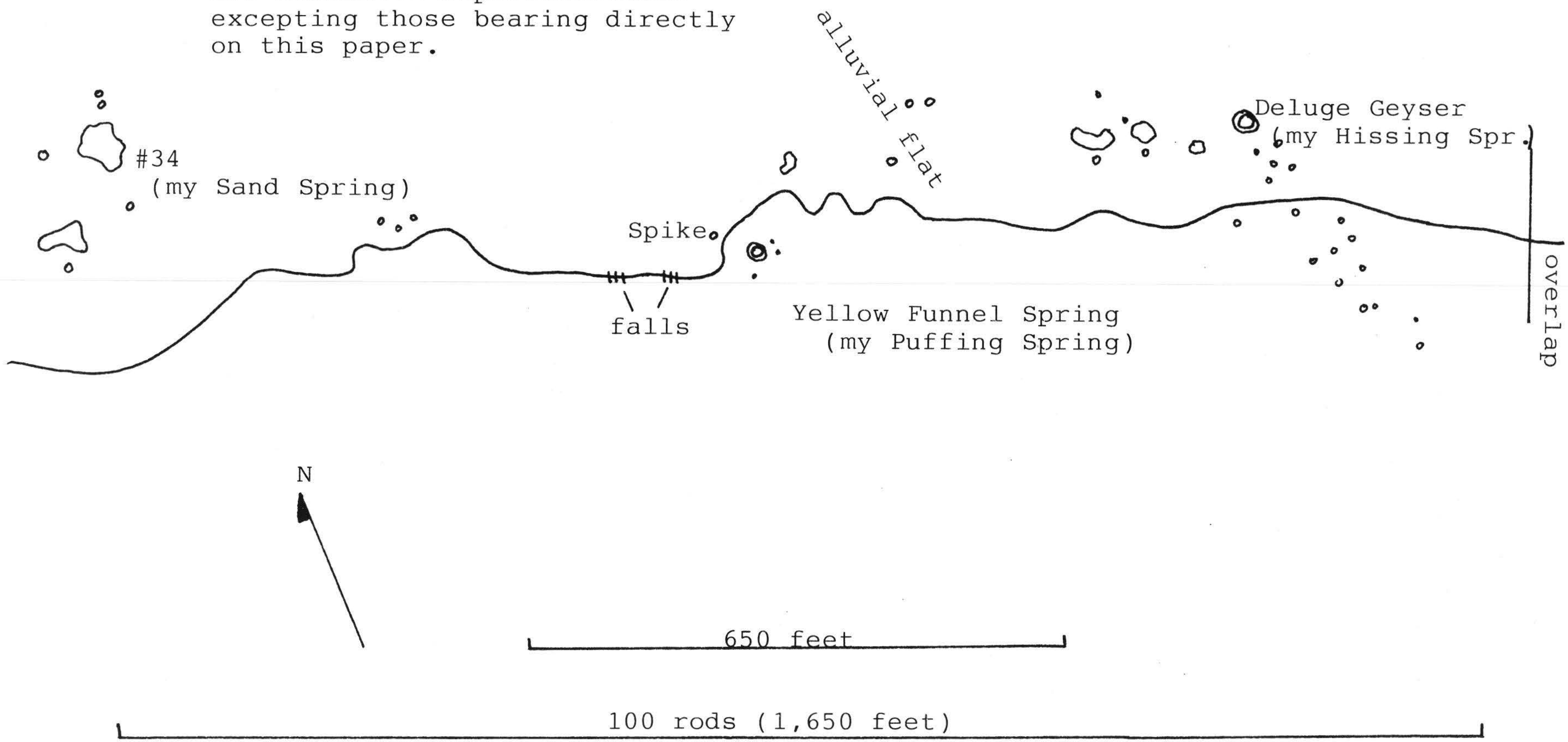


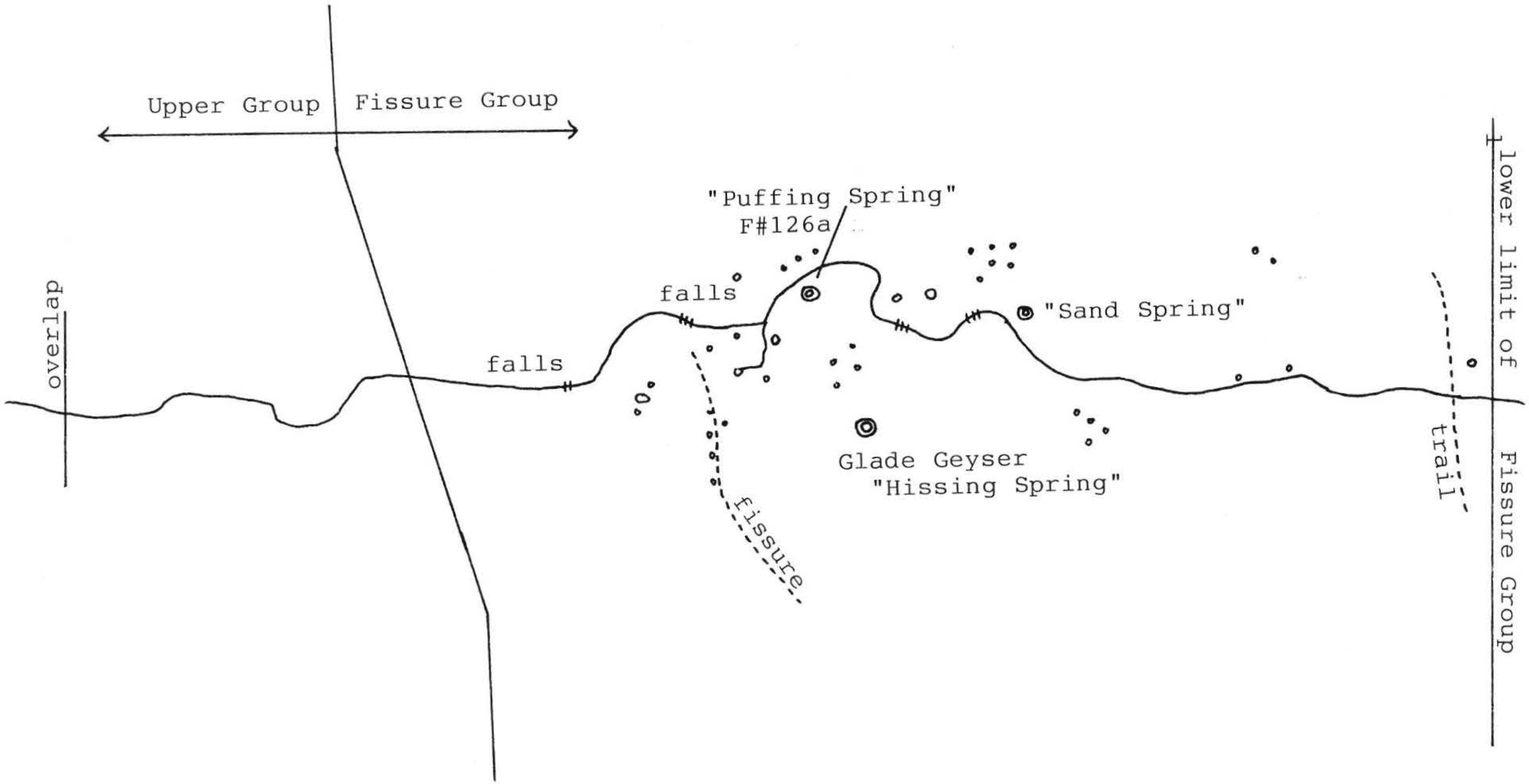
Deluge Geyser, as photographed in 1974, is this author's equivalent of Comstock's "Hissing Spring." Photo by T. Scott Bryan.

Fissure and Upper Groups

Heart Lake Geyser Basin

Based on resized and merged Maps 2, 3 and 4 from Paperiello [1989]. Most of the thermal features shown here are schematic representations excepting those bearing directly on this paper.




Upper Group
Fissure Group
overlap
falls
falls
"Puffing Spring"
F#126a
"Sand Spring"
Glade Geyser
"Hissing Spring"
fissure
trail
lower limit of Fissure Group

A Brief Update About United States Geyser Localities Other Than Yellowstone National Park and Umnak Island, Alaska

compiled by T. Scott Bryan from information provided by GOSA members

Abstract

The status of geyser activity in the other localities of the United States, other than Yellowstone and Umnak, is poor.

Long Valley Caldera, California

The Casa Diablo, Hot Creek, and Little Hot Creek thermal groups were visited by several parties during March–May, 1992. Overall rather little activity was observed.

At Casa Diablo, where there are now two power plants in operation, there was no sign of any activity in any spring. Some of the spring sites near old Highway 395 are now fenced and inaccessible.

It comes as no great surprise that the Hot Creek area is "disappointing". There is a long record of significant geyser action occurring only for a limited time following sizeable earthquakes, of which there have been none for nearly three years. A number of spouters were seen within the spring cluster #9 (of Bryan in *Transactions II*), but the geyser was completely quiet.

An additional geyser has been seen at Little Hot Creek. It plays from a vent mapped but not numbered by Bryan (*Transactions II*) between #s 9 and 11. The height was not more than 6 inches, but the action was entirely periodic, with intervals of 60 to 90 seconds and durations ranging between 30 and 60 seconds.

Steamboat Hot Springs, Nevada

Here there is bad news and BAD news. The bad is that water was visible in only a single feature, and even that slight sputtering came from an opening next to an old drillhole. Only a bit of steam was visible rising gently from a few of the other, larger craters. The BAD news is that Steamboat's second power plant is under construction not more than 750 feet from the Main Terrace. This will certainly spell a complete end to Steamboat Hot Springs as a geyser locality.

Beowawe, Nevada

Although there are reports of "large" steam clouds rising above Beowawe this past winter, they probably arose mostly from the old well [#8, Bryan, this volume]. No geyser gazers are known to have visited Beowawe in several years now, but that any natural spring is active is highly unlikely.

Great Boiling Springs, Gerlach, Nevada

A rumor mill has it that the old campground and spa at Gerlach has been reconstructed and is again open to the public, that one of the pools frequently splashes as high as 5 feet, and that the mud pots are being touted as a special attraction.

Mickey Hot Springs, Oregon

The geyser at Mickey has regressed into being a perpetual spouter; although it continues to reach 2 to 4 feet high and is variable in its force, it has not been seen inactive since sometime during the summer of 1991. This is in keeping with some historical information determined by Anna St. John, a graduate student at Portland State University. It is now known that the geyser has been active, mostly as a perpetual spouter, at least since 1985. The 1991–1992 period of true geyser action is the only such activity known, and corresponds to a time of exceptionally heavy rainfall and high ground water levels. It is inferred that an egress of cool surface water is able to quench an otherwise continuous boiling action at shallow depth, and that this spring can only act as a geyser under those unusual circumstances.

Sunbeam Hot Springs, Idaho

I had never heard of this place before it was reported on by Mike Keller. Although it includes no geysers or spouters at this time, it is the site of "large masses of sinter and the remains of a small geyserite cone." The existing springs are of high temperature, the hottest being 189°F.

Geyser Activity on the Beowawe Terrace
Beowawe, Nevada
An Historic and 1980s Summary

by T. Scott Bryan
all photos by the author

Abstract
By comparing maps and descriptions of the hot springs and geysers on the main terrace at Beowawe, Nevada as they were during the 1940s and 1950s, an attempt has been made to correlate those features with the observed eruptive activity of the 1980s, which activity is also described.

Part I: Correlation of Spring Numbers

Dr. Donald E. White, of the U.S. Geological Survey, began conducting observations of the Beowawe Geysers in 1945; during the succeeding twelve years, he recorded the activity on at least eight different occasions. White, now officially retired but still active with the USGS, is hoping to see through a publication which will more fully describe Beowawe and the geyser action of those early years. In the meantime, a summary of these observations is shown here as Table 1; the source of this data is an unpublished table showing complete annual data, provided to me by Dr. White. Some information has also been derived from Roberts [1989 and personal communication].

Following White's work, Beowawe was largely ignored into the 1970s. I made several visits to the area starting in 1972. In all of them prior to 1986, I found very little activity on the terrace other than a few small mud pots and continuous spouting from two vandalized wells. Accordingly, all detailed observations of those visits were confined to the springs on the valley floor below the terrace. Those results, based primarily on a 1980, trip have been previously reported [Bryan, 1991].

After the onset of commercial fluid production for the Whirlwind Valley geothermal powerplant, which includes a reinjection of fluids into the terrace portion of the Beowawe system, there was a brief but remarkable rejuvenation of the terrace geysers. The activity was separately observed by Koenig [1986] and Bryan [1986]. Table 2 of this paper summarizes those observations and attempts to correlate them with White's earlier observations; these correlations are subject to revision, pending the publication of White's work.

By late 1986, the commercial production had already virtually destroyed the valley springs. The rejuvenations on the terrace were brief, and persisted only into early 1987. No geyser activity has been observed in any part of the Beowawe geothermal system since that time, and it is probable that all geyser action has been irrevocably destroyed by the powerplant development.

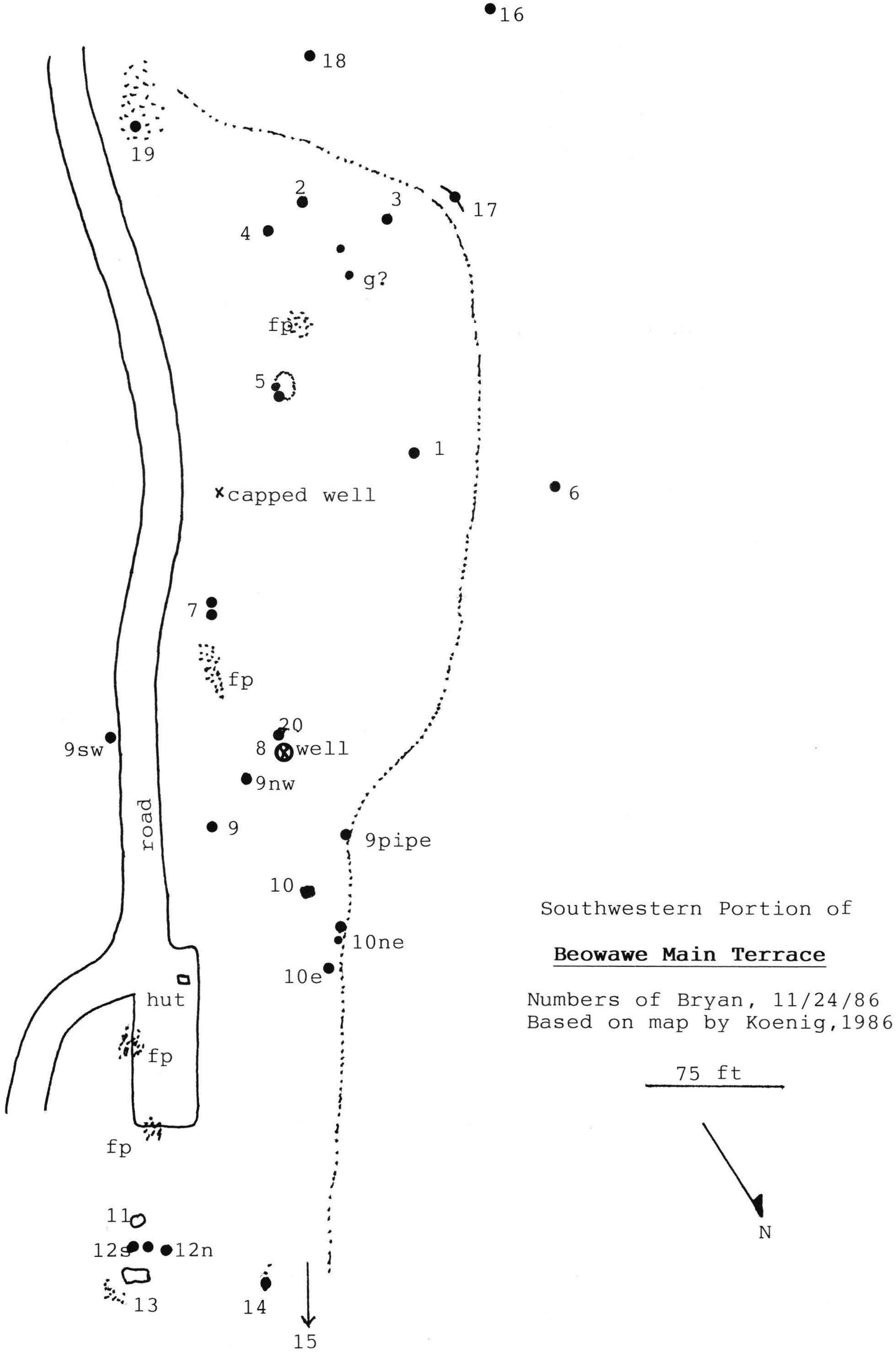
Part II: Activity Observed in 1986

Koenig [1986] made observations of the activity on the Beowawe Terrace on three occasions: June 1-2, 1985, June 15, 1986, and September 18, 1986. Bryan [1986] is based primarily on a single visit on November 24, 1986 but with a background of many prior visits. The following will provide a brief description of the activity observed during these visits.

#1. (Koenig #T1; White #14) **Geyser**

Koenig observed this as an intermittent fumarole in 1985, when the intervals were highly regular with an average of 14m 38s; the average duration was 32s. By June 1986 it had become a geyser, and from that time onward, while it remained highly regular, the intervals gradually increased without a corresponding adjustment in the duration; thus, the geyser was in a decline. The intervals in June 1986 averaged 26m 52s; in September 1986, 46m 36s; and in November 1986, 94m 27s. The durations ranged from 32 to 50 seconds.

#1 was incomparably the most impressive observed geyser at Beowawe during 1986. White had observed its height as up to 2m, about the same as was observed in June and November 1986; in September, however, Koenig estimated some of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15
Southwestern Portion of
Beowawe Main Terrace
Numbers of Bryan, 11/24/86
Based on map by Koenig,1986
75 ft
N

the jets as no less than 4m high. The most impressive portion of the eruption came during the first few seconds of play. It then gradually decreased its force to conclude with a few final hissing puffs of steam. Aligned with the main vent of #1 are two others. Interestingly, Koenig found them to decrease their activity as the main vent was enlarged by the eruptions, to the point that the secondary openings were entirely inactive in September. In November, however, they acted as very loud steam vents throughout the eruption.

Geyser #1, Beowawe's most significant in 1986.

#2. (Koenig #T2; White #6) **Geyser**

No eruption of this geyser was seen by either Koenig or Bryan. Koenig, however, found the runoff channel to be clear of gravel and stained a brown color to a distance of several hundred feet down the slope; also, he could hear heavy splashing at depth. Bryan saw no evidence of recent activity, and the vent steamed only slightly. This appears to be the geyser nicknamed "Tea Kettle" by White; it was among the most impressive of Beowawe's geysers with heights of up to 5m.

#3. (Koenig #T3; White #7) **Geyser**

Similar to #2, this geyser substantially decreased its activity during the span of the 1986 observations. Koenig witnessed two eruptions in June 1986; both were weak and brief (height inches, duration seconds), and could not account for puddles of water on the surrounding sinter. In September the only signs of action were a boiling sound from great depth, and by November #3 appeared and sounded entirely dead. This was probably White's "Spitfire" Geyser, which had long duration eruptions of unstated interval and height during the 1950s.

#4. (Koenig #T4; White #10) **Geyser or Intermittent Spring**

Koenig described this as a simple hot spring, containing quiet, murky water a few inches below the rim. Bryan did not observe an eruption by #4, but at some point during a 20-minute gap in observations this either erupted or overflowed. The state of the runoff channel leading from this spring indicated that such activity was actually quite uncommon and always of very brief duration. This is the same as White's #10, which was a frequent geyser of brief duration and small size.

#5. (Koenig #T5; White #11?) **Perpetual Spouter**

This was an intriguing spring very close to being a geyser. Koenig had it as a "perpetual spouter/fumarole", noting that it ejected enough spray to maintain a small algal pool. In November 1986, the activity was similar but additionally sent spray from some gaps in the surrounding rocks. The distinctly intermittent play reached up to 3 feet high, and there was sufficient discharge to maintain a small runoff stream.

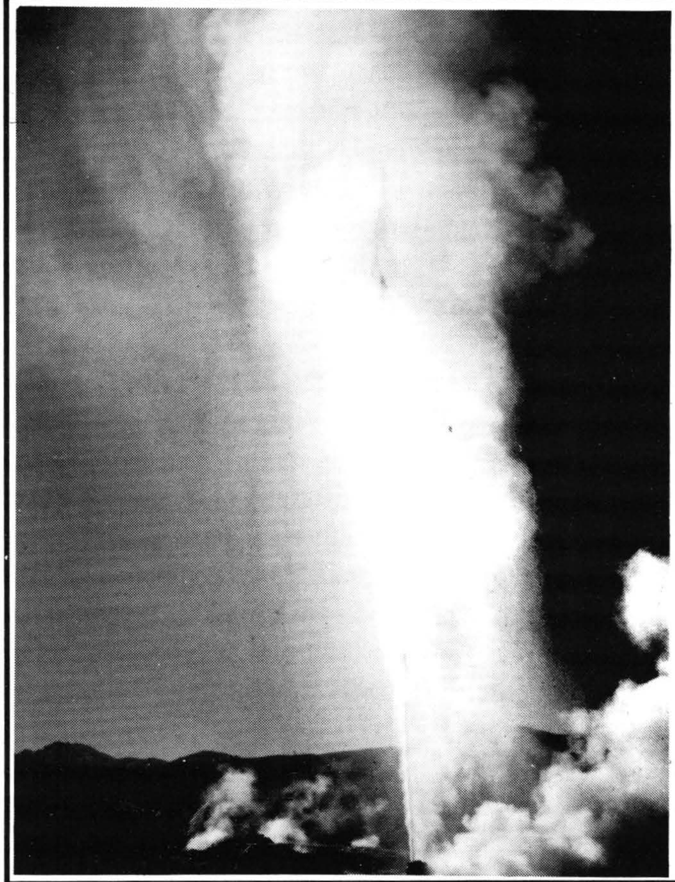
#6. (Koenig #T6; White #21? not a geyser) **Intermittent Spring**

Located down the slope from the rim of the terrace, this spring was active in both June and September 1986. On the earlier visit Koenig was not able to obtain an interval, but he did time one duration as 4m 04s. The average of three observed intervals in September was 18m 08s; durations then ranged from 5m 22s to 6m 14s. The play consisted of a gushing flow of 89°C water from a cave-like vent opening directly onto the hillside. Possibly not even mapped by White, this feature was totally inactive just two months after Koenig's last visit: in the November cold (temperature about 0°C), not even the barest wisp of steam could be seen.

#7. (Koenig #T7; White #17) **Perpetual Spouter**

For Koenig, on all his visits, this was a fluid mud pot, described as "crimson red." In November 1986, it played as a perpetual spouter throwing pinkish water to 2 feet high fromeach of two vents. This was probably the "White Flame" Geyser of White.

#8. (Koenig #T8; White unnumbered) **Erupting Well**



When at its best, the Erupting Well, #8, is easily visible from the I–80 freeway far across Whirlwind Valley.

Drilled during the 1950s, this is one of the two wells that were vandalized in 1971 and then began essentially continuous eruptions. The other well, which is shown on the map, has been capped. The eruption of #8 is impressive, and highly variable. Koenig reported the height as only 10 to 40 feet. In November 1986 I estimated the height to reach a minimum of 40 feet and a maximum height of well over 100 feet. (In 1974, I triangulated this well and obtained a height of 124 feet). There have apparently been occasions when the eruption of this well ceased, for some observers of the 1970s and early-1980s reported no terrace jetting, and in fact Koenig [1986] implies that the well was not in eruption during his 1985 visit.

#9 (Koenig #T9; White #19?) **Geyser**

Briefly described by Koenig as a tiny perpetual spouter ("a small low cone with a small bubbling pool at the top"), this was distinctly a geyser in November 1986. Durations were in excess of 30 minutes long and separated by much shorter intervals; the height was about 1 foot; observations were difficult since #9 lay mostly within the spray of the well, #8.

#9sw (Koenig mapped, not enumerated; White #23) **Perpetual Spouter**

One of several spouting-flowing springs on the uphill side of the roadway, #9sw gave the greatest continuous discharge of any of the observed Beowawe springs in November, 1986. It is interesting, therefore, that Koenig gave it no number or description (although he did show the location on his map). The height of the eruption was as great as 2 feet. There is little question but that this was White's "Orange Spouter" on the basis of both the activity and the rich orange ferric oxide staining of the surrounding rocks.

#9nw. (Koenig not observed; White not observed or possibly #19) **Geyser**

Resembling Yellowstone's "Sputtering Mound/Perforated Cone" Geyser near Lone Star, this had sputtering eruptions out of numerous tiny openings at the top of a low geyserite mound. Observation was difficult as this geyser lay within the spray from the erupting well, #8, but both the intervals and durations were on the order of 1 to 2 minutes; some of the spray reached perhaps 1 foot high. This mound was entirely covered with a spiny, pearly, pinkish sinter, some of the most beautiful geyserite decorations I have seen anywhere.

#9pipe. (Koenig not observed; White #15?) **"Geyser"**

This small geyser erupted from the top of a metal pipe which stood about 6 inches above the bottom of an old natural crater at the rim of the terrace. The eruptions were nearly but not quite perpetual, bursting water up to 1 foot high.

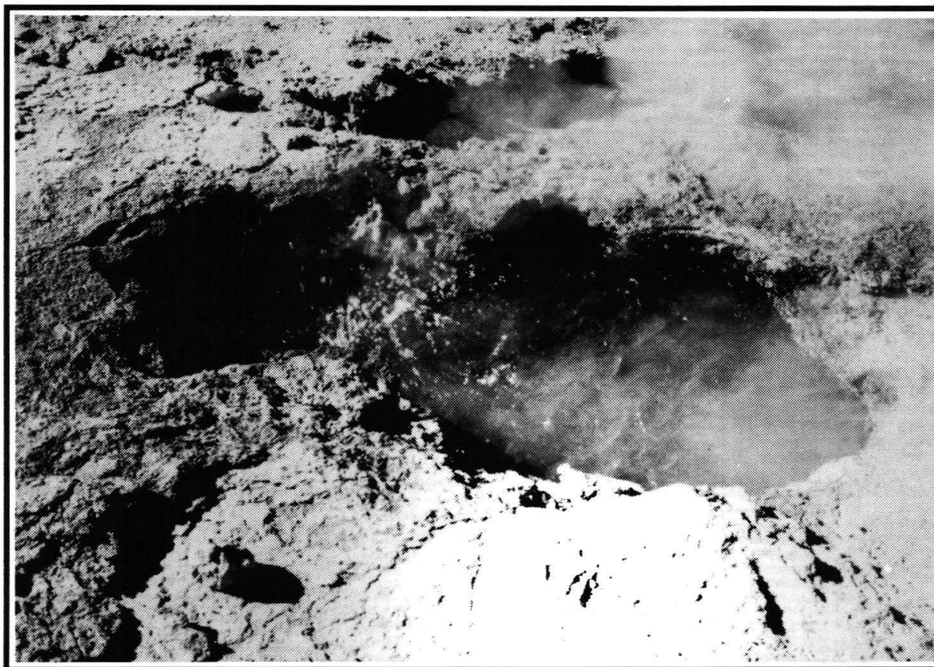
#10. (Koenig #T10; White #20) **Perpetual Spouter or Geyser**

Koenig and Bryan were both impressed by this squarish pool, the largest on the Beowawe terrace, and Koenig noted a similarity to Yellowstone's Depression Geyser. In June 1986 the water level was down fully 3 feet below the rim, but splashes occasionally reached beyond the rim; in September the water level was up to only 4 inches below the rim, but the activity had decreased to little more than bubbling. The water then was a murky, milky-white. By November it had cleared and was superheated ("gravel test")— the only such spring at Beowawe. The eruption appeared to be perpetual with frequent bursts up to 2 feet high, and there was sufficient discharge to maintain a small runoff stream to and down from the rim of the terrace.

Both Koenig and Bryan also noted that this pool was surrounded by a wide area washed clean of gravel, and that the runoff channel could only have been formed by eruptions much larger than observed. Evidently, #10 underwent infrequent but considerable eruptions.

#10ne (Koenig not observed; White #22? not a geyser) **Geyser**

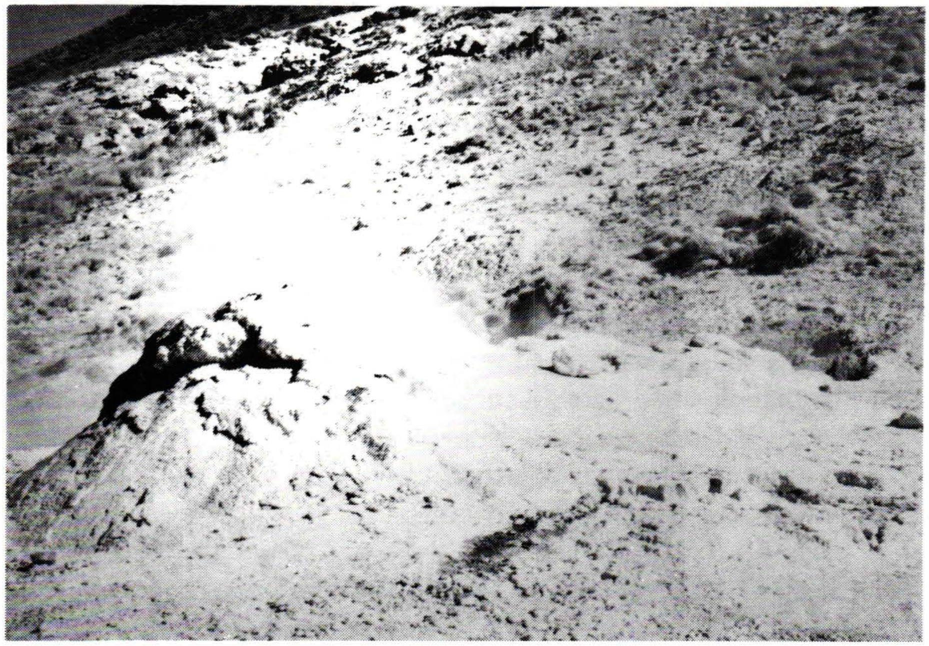
This geyser played from four distinct vents along a fracture running parallel to and immediately at the rim of the terrace.The greatest height, about 1 foot, came from the easternmost vent. The activity was distinctly cyclic: there were five to seven eruptions per cycle, recurring on intervals of 30 seconds and with durations of 2 to 5 seconds; individual active cycles were separated by 5 or more minutes of inactivity. There appeared to be some correlation between this geyser's active periods and episodes of stronger bursting in #10, and again the size of the runoff channel down the terrace face indicated eruptions far stronger than any that were seen.



Geyser #10, shown here during an episode of comparitively minor bursting.

#10e. (Koenig not observed; White #22 if not #10ne) **Geyser**

This was obviously a geyser, active though not witnessed, in November 1986, and it surprises me that it was not observed by Koenig just two months before. It had a distinct crater, about one foot in diameter, which was surrounded by a large washed area drained by a runoff channel which extended far down the terrace slope below. The discharge during eruptions must have been substantial. When first observed the crater



The complex of three sinter cones at #12; #12n is the largest, to the left.

was empty; subsequently it filled very slowly. When observations unfortuately had to end due to impending darkness, the water had reached a point only 2 inches below overflow, was intermittently bubbling, and showed all signs of imminent eruption. The intervals were apparently greater than 6 hours long.

#11 (Koenig #T11; White not shown) **Mud Pot**

Koenig and Bryan made the same observation here: #11 was a light gray mud pot occupying a crater some 5 X 10 feet in dimensions. Interestingly, while Bryan had seen this mud pot in prior years, Koenig noted no activity in it in June 1986.

#12s (Koenig #T12; White #26?) **Perpetual Spouter or Geyser**

Feature #12, as I have designated it, consisted of three parts, labelled #12s, #12c, and #12n. Koenig lumped all three vents together as #12, noting that this might be the same as Nolan and Anderson's [1935] "Double steam vent" on their map. White identified my #12s and #12c as his #26, and my #12n as his #27 (apparently).

#12s jetted pinkish water out of its geyserite cone from a water level several feet down; I estimated the true height of the eruption to be at least 6 feet but mostly subterranean. Because of a large runoff channel leading from this cone, it appeared that #12s underwent relatively frequent eruptions of considerable size.

#12c (Koenig #T12; White #26) **Fumarole or Geyser**

Koenig apparently noted this along with my #12n as "a pair of noisy fumaroles." Such was the activity in November 1986, when #12c's discharge was loud enough to attract attention at a considerable distance; there was some variation to the force, and I believe it was once heard from the valley floor. White had noted this as a subterranean geyser, and both Koenig and Bryan noted the presence of washed areas and runoff channels leading away from the cone.

#12n (Koenig #T12; White #27) **Fumarole**

Although this was a geyser called "Pin Cushion" by White, this was a only rubble-filled, gently steaming cone for both Koenig and Bryan.

#13. (Koenig #T13; White not shown) **Mud Pot**

This was a large pink mud pot, with crater dimensions of about 10 X 20 feet. Koenig noted a "mudflow" extending downslope from the crater. In November 1986 that was not evident; instead, the thick mud was being thrown in large clumps as high as 6 feet, and several small mud volcanoes were developing within the crater.

#14. (Koenig #T14; White #28) **Geyser?**

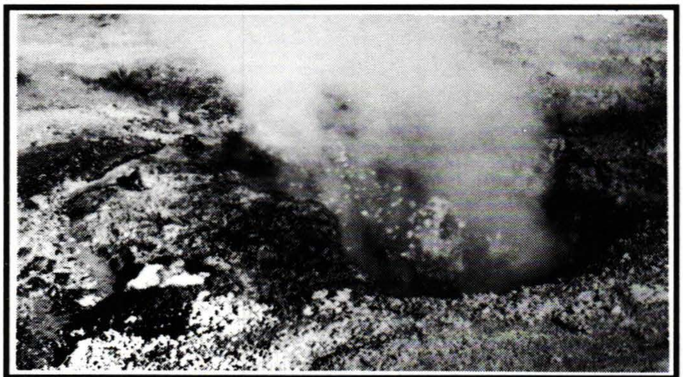
Koenig noted that this eight-foot long crack had "cleared itself out", and that boiling water could be heard at depth. In November, however, only a slight bit of steam escaped from the vent, and no sound of liquid water could be heard.

#15. (Koenig #T15; probably White #29) **Geyserite Cone**

Located northeast of #14 and off the area of the map, this impressive geyserite cone was described as "dead" by Koenig, but could be seen to steam slightly in the cold of November. This is probably White's "Beowawe" Geyser, which he observed erupting as high as 9m during the 1950s.

#16 (Koenig #T16; White #4) **Geyser**

Koenig described this as a perpetual spouter, but noted the possibility of greater activity on the basis of a wide runoff channel. Indeed, during November 1986 this was one of Beowawe's better geysers. Activity was virtually constant, but every 1 to 2 minutes it would be punctuated by surging, bursting eruptions up to 3 feet high; the duration of these surges was typically between 5 and 10 seconds



Geyser #16 in eruption. Note the runoff area to the left.

and produced substantial runoff. During the remainder of the time, the splashing reached not more than 6 inches high.

#17. (Koenig #T17; White #8?) **Geyser**

White listed this as a geyser but gave no data; Koenig says that it was probably a geyser, as the area surrounding the cone was clear of gravel and boiling could be heard at depth. In November 1986 this feature was so inactive that I made no observation of it.

#18. (Koenig not shown; White not shown) **Perpetual Spouter**

In November 1986 this small vent acted as a perpetual spouter about 1 foot high. Its runoff channel was lined with a lush growth of algae.

#19. (Koenig frying pan area; White not shown) **Geyser**

This one was a surprise. Within an area of small frying pans, this vent unexpectedly produced an eruption fully 1 foot high. I obtained no eruption data as the play began while I was elsewhere on the terrace, but the duration was long.

#20. (Koenig not numbered; White #18?) **Perpetual Spouter**

Almost not observed due to its position close to erupting well, #8, this appeared to be a perpetual spouter. The eruption reached about 2 feet high from each of two closely-spaced vents. It is possible that this is not a natural feature but openings related to the well.

In the area further to the northeast from #15 are numerous additional hot spring vents. This area included several of the geysers observed by White. In 1986, however, none of these vents were involved in the rejuvenation seen elsewhere. A cursory check found several to steam considerably, but nowhere was there evidence for liquid water.

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Nolan, T.B. and Anderson, G.H., 1935, The geyser area near Beowawe, Eureka County, Nevada: American Jour. Science [5th Series], vol.27, no.159, p.215–229.

Roberts, J.A., 1989, The Beowawe geysers— an historical overview: The Geyser Observation and Study Assoc., *Transactions* , vol. I, p.255–293.

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TABLE 1

Beowawe Geysers Enumerated by White

The following geysers were noted by Dr. D. E. White and reported in a table dated 4/1/87. This is a summary of observations performed on: 9/22/45, 9/1-2/47, 5/14/48, 9/8-9/49, 9/30-10/1/50, 5/25/51, 10/15/51, and 9/1/57. Names are informal, by White.

No.	Name	Interval	Duration	Height	Notes
6	"Tea Kettle"	3-6 min	1-5 min	2-5 m	I=60-70 min in 1957
7	"Spitfire"	long	40 min	not stated	
8					No data stated
10		30 min	1 min	0.3-0.8 m	
11					No data stated
13				to 5 m	
14				to 2 m	
15					No data; subterranean
17	"White Flame"	10 min	2 min	>1 m	
18				>1 m	
19					Active if not cooled by #23
20					No data; subterranean
(23	"Orange Spouter"				Perpetual spouter; see #19)
24				<1 m	
25			12-13 min	3 m	Disintegrating cone
26					No data; subterranean
27	"Pin Cushion"				No data; multiple vents
28				to 0.3 m	
29	"Beowawe"	150 min	2 min	7-9 m	
30					No data; 2 erupting pools
31				to >1 m	
32					No data
33 & 33e					No data; two vents alternate

36				to >2 m	
37				small	
38				small	Two vents
39				1.3 m	
42					No data
43					No data
45					Never observed active
48				0.3 m	
(49	"Colorful Spouter"				No data; disch. ≈30 L/m)
51	"Frying Pan"	10 min	40 min	[0.3m]	On valley floor

TABLE 2

Observed Activity at Beowawe, Nevada
as conducted by White, 1951; Koenig, 1986; and Bryan, 1986

Spring Number			Observed Activity			
White	Koenig	Bryan	White	Koenig	Bryan	Comments
14	1	1	g	g	g	Largest, most regular geyser in 1986; height variable, 4-15'
6	2	2	g	g?	dormant	Fresh runoff, subt. splashing, 9/86; quiet and dry, 11/86
7	3	3	g	g	dormant	Wet areas not accounted for by obs. minors of 4-6", 9/86
10	4	4	g	pool	g/i.s.	Unseen overflow between observations, 11/86
11?	5	5	g	p.s./s.v.	p.s.	Steamy spouting 1-3", 9/86; spouting 1-2', 11/86
21?	6	6	spr	i.s.	dormant	I=18m; D=5-6m; strong flows, 9/86; no recent action, 11/86
17?	7	7	g	m.p.	p.s.	Fluid mud, 6/86 & 9/86; murky spouter to 2', 11/86
---	8	8	–	active	active	Erupting well, variable height 40-100'
?	9	9	g	p.s.	g	True geyser, 11/86; I≈10m; D=30-40m; H=1-2'
15 or 16	–	9pipe	g or i.s.	not obs	active	Erupting 1.5" diameter pipe, play to 1', 11/86
19?	–	9nw	–	not obs	g	Intermittent sputtering geyser, H=6-12"; pearly geyserite, 11/86
23	–	9sw	p.s.	pools	p.s.	Spouting pool w/ other springs at base of hillside, active 11/86
20	10	10	subt g	p.s.	p.s./g	Spouter to 3+' from w.l. -3', 6/86; near full but weaker, 9/86; superheated (205°F) spouter to 2' with overflow but not reaching washed areas, 11/86
22?	–	10ne	spr	not obs	g	Cyclic geyser playing from multi-vent rift at brink of terrace; cycle D=3m followed by Pause≈2m; action within cycle I=30s; D=4-5s; H=2', 11/86
22?	–	10e		not obs	g	Not observed; crater filling slowly, wide washed area and channel
not shown	11	11	–	m.p.	m.p.	Gray mud pot with small cones, 1986
27	12	12n	g	s.v.	s.v.	Vent choked with rubble; gentle steam, 1986
26	12	12c	subt g	s.v./g?	g?	Strong, noisy steam vent with washed areas on and near cone

26	–?	12s		not obs?	m.p.	Pink mud pot in deep muddy crater, 11/86
not shown	13	13	–	m.p.	m.p.	Pink mud pot with lava-like flows of mud, 9/86 and 11/86
28	14	14	g	g	s.v.	Small geyser, 9/86; quiet steam vent, 11/86
29 or 30	15	15	g	"dead"	s.v./g?	Weak steam vent within distinct cone, possible runoff, 11/86
4	16	16	spr/g	p.s.	p.s./g	Strongly cyclic spouter, some very brief pauses, H=2-3', 11/86
8?	17	17	g	g?	dormant	Gurgling at depth, cleanly washed, 9/86; no steam at 30°F, 11/86
not shown	–	18	–	not obs	p.s.	Small spouter, H=1', with lush algae, 11/86
shown	–	19	2 vents	f.p. area	g	Began long eruption between obs. within f.p. area, H=1', 11/86
18	–	20	g	f.p.	p.s.	Spouting clear water from two vents, H=2', 11/86
24	–	–	g	f.p.	f.p.	
25	–	–	g	f.p.	f.p.	

This photograph showing "The Beowawe Geyser" on the Beowawe Terrace was taken circa 1950. Several different people have identified it as several different features, so its actual identity is unknown. Photo courtesy of the Nevada Department of Highways and Parks archives, Carson City.

The Geysers of Umnak Island, Alaska

A Summary

a compilation by T. Scott Bryan
With Photographs, Editorial Corrections and Permission for Publication
by S.A. Liss, Alaska Division of Geological and Geophysical Surveys

Abstract

Geologists with the Alaska Division of Geological and Geophysical Surveys have recently completed a study of the geysers and other hot springs along Geyser Creek, near Geyser Bight, on Umnak Island. Although the total number of enumerated springs is small, at least 12 active geysers have been observed during the years since 1947, making Geyser Bight among the most significant geyser fields in the world.

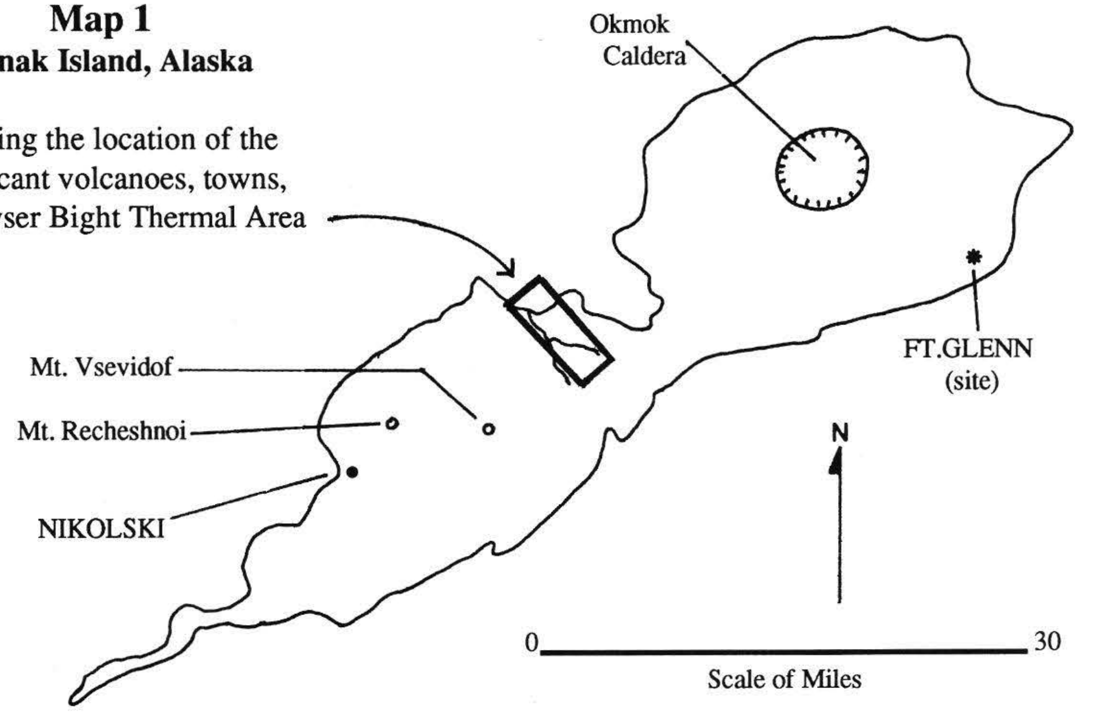
Location

Umnak Island is among the larger of the Aleutian Islands, located in the eastern part of the chain. It is the fourth significant island (after Unimak, Akutan, and Unalaska) west of the Alaska Peninsula; it is immediately west of Unalaska, where the community of Dutch harbor (population 3,000) serves as a regional fishing, transportation, and trade center. Umnak, however, is considered quite remote, lying some 1,000 miles from Anchorage. The only permanent residents are at the small town of Nikolski (population 60), near the far western end of the island. There is neither road nor trail from Nikolski to Geyser Bight. Although the town is served by Reeve Aleutian Airways, gaining access from Nikolski would require a very rugged hike. It is doubtful if one would be able to trek overland via this route; the straight line is just 25 miles, but one would have to divert far upstream around the Black River, which is probably impossible to ford. Old maps show a Ft. Glenn at the eastern end of the island and a road leading from there to a point near the Geyser Bight springs, but this World War II facility was abandoned decades ago (excepting an occasional solitary Aleut sheperd).

Access to Geyser Bight was achieved by the geologists of the Alaksa DGGS by flying charter airplanes from Dutch Harbor to Nikolski. They were

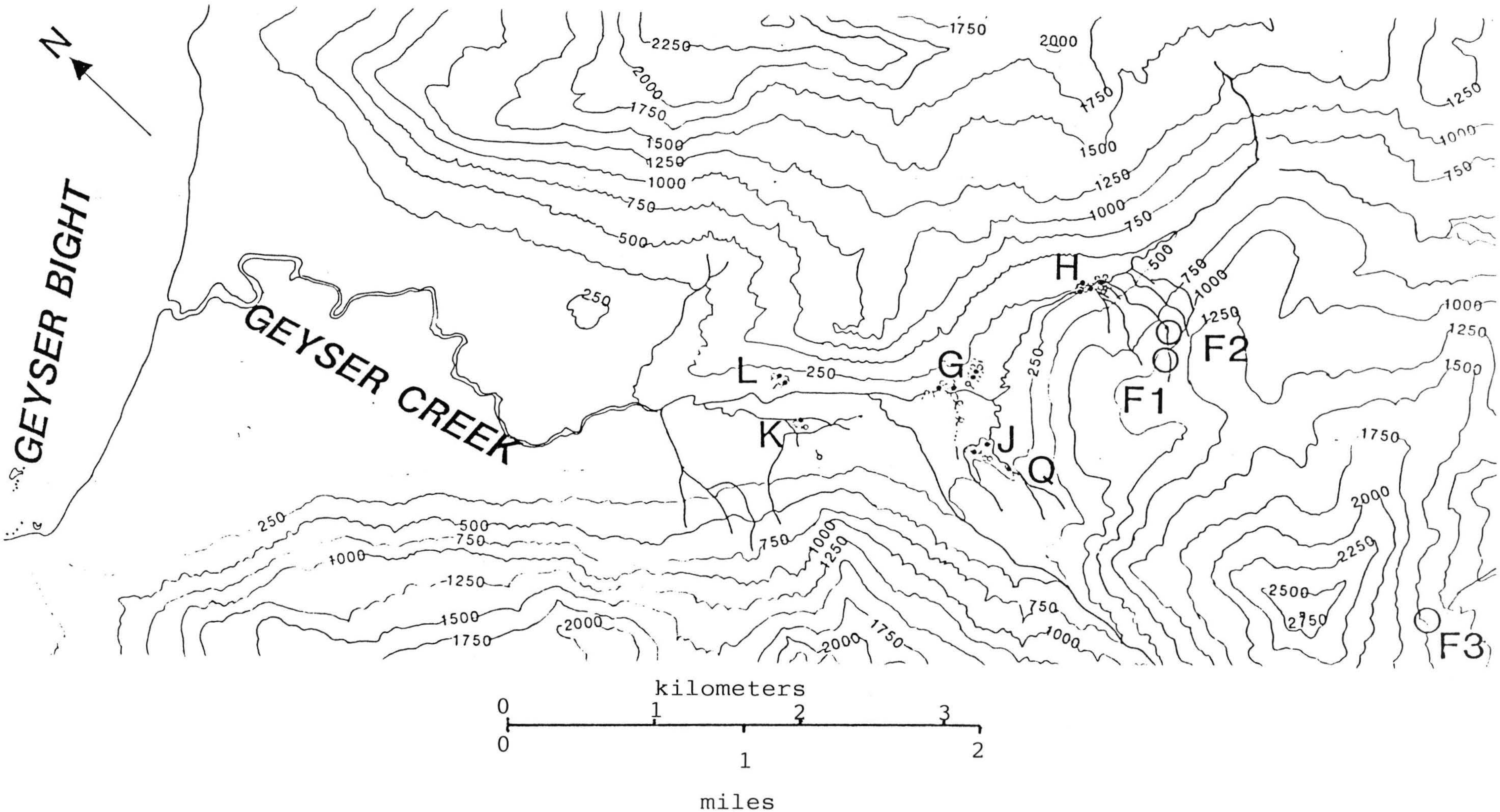
Map 1
Umnak Island, Alaska

Showing the location of the significant volcanoes, towns, and Geyser Bight Thermal Area



Map 2

Geyser Bight Geothermal Area
Umnak Island, Alaska



An overview of the central part of the Geyser Bight thermal area. Springs in the foreground comprise Area J. The Area G springs are visible at the base of the slope towards the upper left, while Area H is out of sight up the valley to the top right of the photo.

equipped with two Zodiacs (rubber inflatable boats) and motors, which were used to make a water trip to the Geyser Bight shoreline. No matter what kind of travel can be arranged, getting to these geysers is expensive and subject to severe and rapidly changing weather conditions.

General Geology

As is the case with all the Aleutian Islands, Umnak's geologic history is entirely volcanic (with superimposed glacial action). There are three significant volcanoes on the island. Most important is Okmok Caldera. It is a 10 km diameter collapse caldera which initially formed roughly 8,250 years ago. A second, similar eruption took place about 2,400 years ago [Miller and Smith, 1987]. Dozens of associated cinder cones and domes lie both inside the caldera and on the flanks of the volcano, and among these have been at least 18 eruptions since the year 1760. One of size happened in 1945, there were numerous small-scale ashy outbursts during the 1970s, and an explosive ash eruption in 1988.

The other two volcanoes have been comparitively less active. Mt. Vsevidof has had five eruptions since 1760. Mt. Recheshnoi has had no historic eruptions, but one very large lava flow reached the ocean about 3,000 years ago.

Hot springs were first reported on Umnak by Grewingk [1850], but he did little more than note their existence. Dall [1870] was the first to report on the presence of geysers, including that now specifically known as G6. They were later noted by Waring [1917], but again with virtually no details. From that time, no further visits of a geological nature were paid to the springs until 1947, when Byers and Brannock noted the presence of several geysers among a number of letter-designated spring groups.

Distinct geological reports have now been produced on the basis of visits during 1947 [Byers and Brannock, 1949], 1973 [Barnes, 1973], 1980 [Motyka, et al., 1981], and 1983, 1986, and 1988 [Motyka, et al., 1992, and personal communciations]. This paper summarizes the results of these studies, concentrating on the geysers that make this one of the United States' most significant geyser fields.

Umnak Island and the location of the Geyser Bight spring area is shown on Map 1.

The Geyser Bight Hot Spring Sites

The stream draining the valley which contains the Geyser Bight Hot Springs is known as Geyser Creek. The springs are inland some 4 to 7 kilometers southeast of Geyser Bight itself, in the north-central portion of Umnak Island. The elevation among the springs ranges from about 30 to 110 meters; the fumarolic areas range as high as about 500 meters.

The hot springs are distributed among nine small and distinct hot spring groups, designated as Sites F1, F2, F3, G, H, J, K, L, and Q (Map 2). Each of the individual thermal areas has been mapped in detail, but those maps are omitted from this summary report.

Sites F1, F2, and F3 contain only fumaroles and acid springs such as mud pots. Each of these zones contains one notable superheated fumarole among other lesser vents. Those at F1 and F2 were recorded respectively at 100.2°C and 102.0°C during 1988. The fumarole at F3 is especially significant. Its minimum temperature was 125°C as it jetted a pressured plume of mixed steam and water over 30 meters high. In the words of Motyka, et.al. [1990], "Gasses emanate from the vent forcefully enough to expel rocks 5 cm in diameter which are thrown into it."

Site G contains nine springs that have been observed variously as geysers, perpetual spouters or ebullient boiling vents. These springs can be neatly subdivided into two sub-groups with numbers G1 to G6 in an upstream area separated by some 100 meters of warm ground and seeps from numbers G8 to G12 in a downstream area; spring G7 of 1947 could not be located during the 1988 studies. All of the springs are located in the valley bottom, within about 70 meters of the East Fork of Geyser Creek or its tributaries. No net discharge was reported for this group in 1988, but the total flow recorded from individual springs amounted to 1,000 liters/minute (l/m).

Site H matches Site G for its number of erupting and boiling springs. Located about 1 km further up the East Fork of Geyser Creek, its springs are also confined to a zone within a few meters of the stream. The total discharge of Site H was 2000 liters/minute in 1947, down to only 650 l/m in 1980, but then back up to 1,900 l/m during the 1988 observations. Corresponding to these water flow changes have been significant variations in the geyser behavior, with previously unobserved geysers being seen during 1988.

Area J lies a short distance southwest of Area G. It presumably was once a more active spring group, as it is drained by a nearly defunct stream channel, and the discharge by the springs in 1988 was substantially less than it had been in 1947. Here, however, are found the only deep, clear, funnel-shaped and sinter-lined pools of the Geyser Bight area. One is a geyser, and another might be. Pool J1 discharged an estimated 720 l/m in 1947. That was down to just 10 l/m in 1988, but although the surface temperature was only 80°C, distinct rumblings and concussions could be heard and felt next to the pool.

Sites K, L, and Q contain only smaller and cooler springs (temperatures to 86°C, but mostly much lower). No geysers have been recorded among these sites.

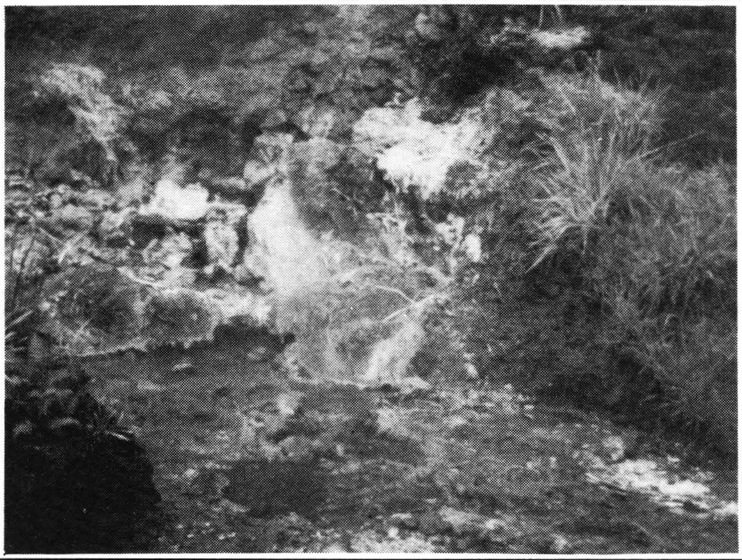
The Geysers of the Geyser Bight Hot Springs

I personally knew virtually nothing beyond the existence of the Geyser Bight springs prior to the Fall of 1989. At that time, I obtained a copy of Motyka, et.al. [1981] and followed up with letters to all three authors. At various times, both Motyka and Liss have replied with additional data and answers to questions.

It seems that at the outset, the geologists with the Alaska Division of Geological and Geophysical Surveys (DGGS) used a very rigorous definition for "geyser." Only those features with long and distinct intervals and relatively large bursting were included. Other features were listed as ebullient boilers and fountains, some or all of which might actually prove to be geysers upon more concerted observation. This fact has now been recognized in Motyka, et.al. [1990], where a couple of features had their listings converted to "geyser" as a result of the 1988 studies and communications with me. They have also included Dr. Donald E. White's [1967] USGS definition within the text.

The geyser activity, as observed during studies conducted in 1947, 1980, and 1986/1988 is summarized by Table I. The following descriptions will provide information about the characteristics of the individual geysers and other intermittent or spouting springs.

G1. This is a cluster of vents. G1b, c and e all exhibited ebullient boiling (intermittent?) and fountaining as high as 30 cm during 1988. G1c was a true geyser in 1980, when extremely brief eruptions recurred every 1 to 3 seconds.



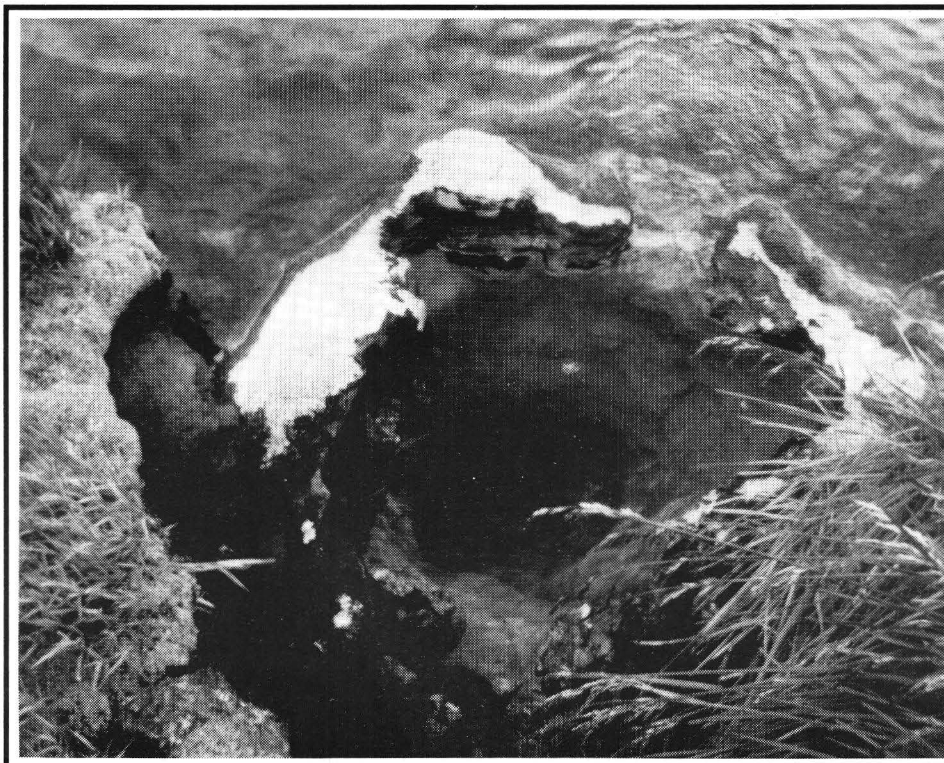
Spring G3.

G2, G3, G4. These three springs lie near one another along with several smaller vents. Leading from them downslope to the stream is an extensive sinter apron fully 5 meters wide. These springs behaved as perpetual spouters during 1988; G3 was a small geyser similar to G1 c in 1980.

G5. Is a steaming vent over 2 meters in diameter. It does not discharge, but water could be heard boiling deep below ground beyond the reach of a thermometer in both 1947 and 1988; it was not observed in 1980.

G6. This emerges from a sinter cone situated between two thermal pools. Although described as boiling (apparently continuously) in 1980, field notes by Liss in 1988 indicated only a constant and very slowly flowing gas with no violent bubbling and no actual boiling. A photo taken in 1988 by Liss shows a quiet pool with one large steam bubble rising through the water, implying discontinuous action. G6 had only quiet discharge in 1947.

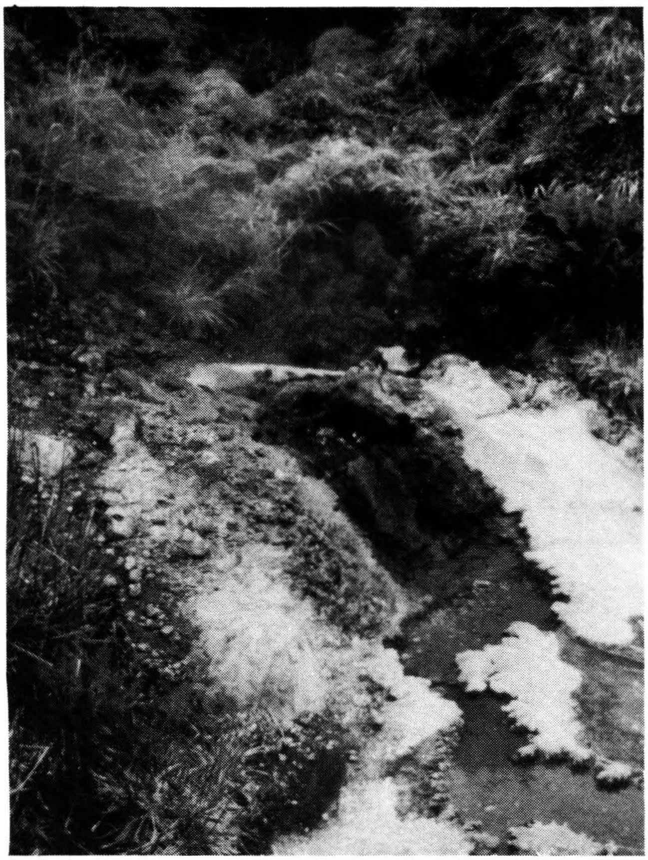
G8. This is the most significant and most permanent geyser at Site G, recorded as active in 1870 [Dall, 1870; fountains to 60 cm], 1947, 1980, and 1988. It has always had intervals ranging between 10 and 12 minutes. The eruptions last about 1 minute. Through the years, however, the observed height has gradually decreased so that the 1988 eruptions were not more than 20 cm high. The play emerges from numerous small openings among cemented rocks within a shallow sinter bowl about 1 meter in diameter. The total discharge is 750 liters per eruptive cycle, and the water flows over a 5 X 25 meter sinter apron into Geyser Creek.



The cone and small pool of Spring G6. Note the rising gas bubble.

G8a. Lies a few feet from G8 and was not observed at all in 1947. By 1980 it had become a seeping spring, and in 1988 it was a variable ebullient boiler.

G9, G10. Both of these springs are perpetual spouters which play from small sinter cones and flow across small sinter terraces. The height of each was just a few centimeters. There is a measured discharge of 54 l/m from G10, but a photo by Liss appears to show no discharge from G10, implying variable activity.



Spring G9

H1. H1 is the most active spring at Site H. It was distinctly a geyser in both 1947 and 1980, when the intervals were between 1 and 3.5 minutes. The play consisted of violently boiling water sending fountains up to 70 cm high. It was not observed to pause its action during 1988, when the play was fully as strong as before.

H2. This was listed as a geyser in both 1947 and 1980. In 1988, H2 was described by Motyka, et.al. [1990] as a perpetual spouter erupting from two vents to as high as 10 cm. The net discharge was 40-50 l/m, and several spouters were located nearby.

H4. This was a geyser of irregular activity during 1988. When first seen, it was playing constantly to about 40 cm throughout several hours of observation. The next day, however, it showed intervals of 3 to 11 minutes and durations of 2 to 3 minutes. These eruptions commonly began with play to 50 cm, which then declined to only 10 to 20 cm before abruptly stopping as the pool drained. By the third day it again appeared to play constantly. It might be, therefore, that this is a cyclic geyser, with long eruptions either starting or ending an eruptive series.

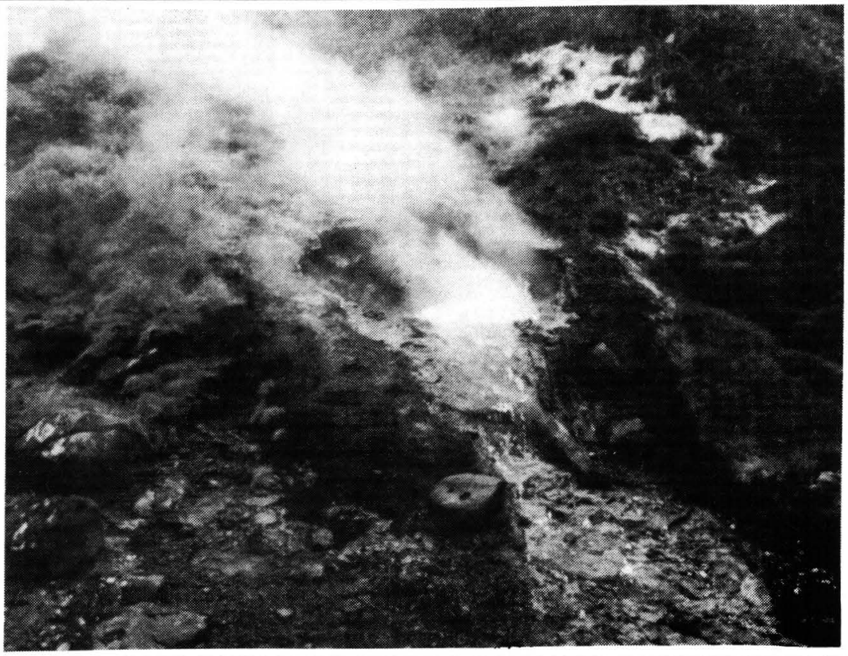
H5. A geyser during 1947 and 1980, the site of H5 could not be located during the 1988 studies. This seems to be in keeping with dramatic changes at Site H, where geysers H10 and H11 were not observed at all prior to 1988, and where the total water discharge has ranged from only 650 l/m to as much as 2,000 l/m through the observed years.

H6. Although only observed to boil during 1988, the action of H6 was strong enough for Motyka, et.al. [1990] to suggest it as a geyser. The fountaining was up to 10 cm high while a smaller nearby vent quietly bubbled.

H7. A geyser during 1980, with intervals of 3 minutes, H7 was only a quiet, gassy pool in 1988.

H8. This spring was not distinctly recorded during either 1947 or 1980, as it was a minor quiet pool. However, a single eruption observed during 1988 makes this the largest of the Geyser Bight geysers. The one witnessed eruption had a duration in excess of 10 minutes, during which the continuous bursting reached fully 2 meters high. Discharge during the eruption was about 100 l/m.

H10. Never observed prior to 1988, this spring had nearly continuous eruptions about 30 cm high. The crater is a symmetrical sinter bowl about 1 m in diameter.



Spring H10 in eruption

No actual, true eruption was seen.

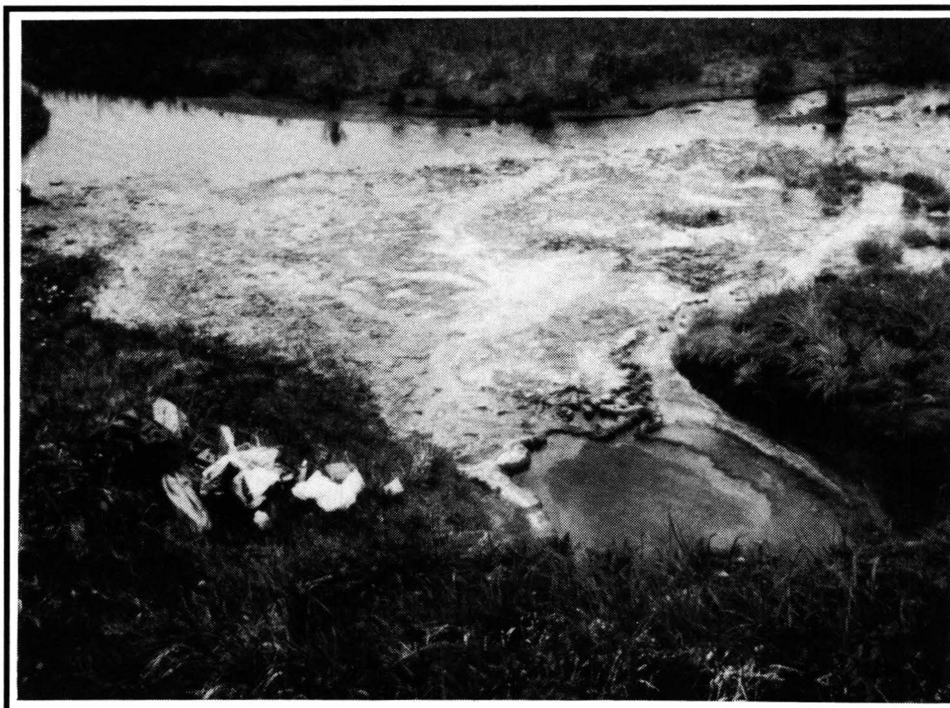
J6. Motyka, et.al. [1990] list this as a quiet pool, not a geyser, but their description notes that "gas occasionally breaks the surface of the calm [4 m diameter] pool." This, like J5, might therefore be classed as a gassy geyser.

Summary

In 1988, the Geyser Bight Hot Springs included not fewer than 6 true geysers, and at least 2 additional springs might well have been classed as such. There were also at least 8 perpetual spouters and 2 variable/intermittent boiling springs. This gives a total of 17 erupting and/or intermittent springs. In addition, including geysers observed prior to but not during 1988, the total number of geysers observed at Geyser Bight is not less than 12. Given that only 35 individual springs were actually enumerated during the course of the Geyser Bight studies, that 48% were eruptive and that 34% either are or have been true geysers is remarkable, and makes Geyser Bight a very

H11. Also never observed prior to 1988, H11 was listed as a definite geyser with intervals of 1 to several minutes during which the fountaining reached 40 cm. During the "quiet" interval, the play reached some 10 cm high and was never observed to cease. Thus, this might more accurately be termed a variable perpetual spouter, even though Motyka, et.al. [1990] make a point of listing this as a geyser.

J5. This is an oblong pool, about 1 X 1.5 meters, at the head of a 20 X 20 meter sinter apron. A quiet pool with a steady discharge of 25 l/m most of the time, about hourly the discharge fully doubled as the spring "erupted" in 1988. The indication is that this, along with nearby J6, might be a gassy geyser. The activity is powered by mixed "gas and steam", and the pool temperature is only about 90°C (92.2°C in 1980), thus nearly 10°C below boiling.



Spring J5

significant geyser field. Since the demise of Steamboat Hot Springs and the Beowawe Geysers of Nevada because of geothermal powerplant developments, the Geyser Bight system is now the second largest in the United States.

Acknowledgments

My personal thanks go to Dr. Roman J. Motyka and Shirley A. Liss, both with the Alaska DGGS, for responding to my query letters and providing information not included in their published reports. Liss also sent a preliminary draft version of the spring descriptions based on their 1988 observations and a large packet of photographs, with permission to reproduce the photos. They are an invaluable record of the Geyser Bight springs and their activity, and will be maintained as a part of the GOSA archives.

This publication has been prepared by T. Scott Bryan for GOSA. The text has been thoroughly revised and edited by Liss, who also wrote: "... we certainly do not object to having it published in the Transactions. Matter of fact we agree it is a good idea..."

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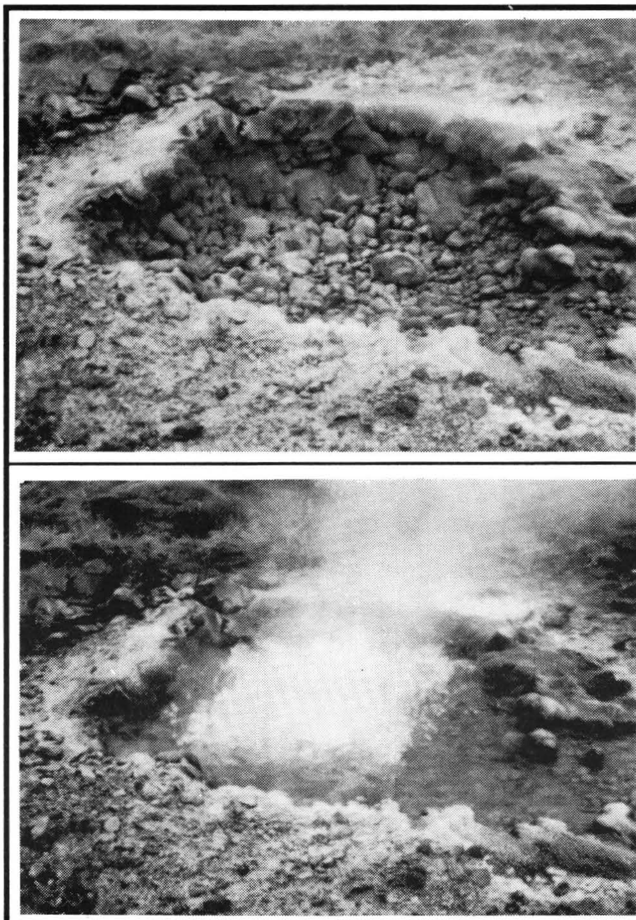

Spring G8 shown quiet (top) and in eruption (bottom)

<u>TABLE I</u>

Geysers of the Geyser Bight Area, Umnak Island, Alaska

A Summary of Observed Activity in 1947, 1980 and 1988

Spring No.	1947	1980	1988	Interval	Duration	Height	Comments
G1	spr	**G**	ps	1-3 seconds	splash	30 cm	This and all other ps
G2	spr	n.r.	ps				previously recorded as
G3	spr	**G**	ps				**G** geysers might prove
G4	spr	n.r.	ps				to be **G** upon more obs.
G5	boil	n.r.	boil				Subt. ps or **G**
G6	spr	boil	bubble	intermittent	no data		Photo shows quiet pool
G8	**G**	**G**	**G**	10-12 min	1 min	20-60 cm	Disch. 750 liters/cycle
G8 a	n.r.	spr	boil	intermittent			Variable boiling
G9	spr	spr	ps				
G10	ps	spr	ps				Photo ind. variable
H1	**G**	**G**	ps	1-3.5 min		70 cm	Data of 1947 and 1980
H2	**G**	**G**	ps	seconds	seconds	10 cm	
H4	spr	boil	**G**	3-11 min	2-3 min	10-50 cm	?Long-term cyclic action
H5	**G**	**G**	n.r.	20 sec			Could not be located, 1988
H6	spr	ps	boil (?**G**)	near steady			Believed probably g, 1988
H7	spr	**G**	spr	3 min			Gassy bubbler, 1988
H8	n.r.	n.r.	**G**	unknown	> 10 min	2 meters	Only one eruption seen i.e.
H10	n.r.	n.r.	ps/**G**	near steady		30 cm	
H11	n.r.	n.r.	?**G**	1-sev. min		40 cm	Highly variable ps?
J5	n.r.	**G**	**G**	1 hour	1 min	bubbling	Deep pool w/ sinter apron
J6	n.r.	spr	spr/?**G**				Text ind. possible **G**

Abbreviations— **G**=geyser; ps=perpetual spouter ("fountain"); boil=intermittent ebullient boiler; spr=quiet spring; n.r.=not recorded

1988 Summary— Active geysers observed=6; probably geyser=1; perpetual spouters=8; intermittent boilers=2
Total Number of Intermittent and/or Erupting Springs, 1988 = 17

<u>Overall Summary— Total geysers observed, 1947+1980+1988 = 12</u>

A Bibliography of the Geysers of the World
Excluding the United States

compiled by T. Scott Bryan

In 1989, then–editor of *The GOSA Transactions* Tomas Vachuda suggested that one thing GOSA lacked was a thorough compilation of references to geyser activity. The following list may provide a start.

There is a bibliography in my book, **The Geysers of Yellowstone** (all editions), but it is very abbreviated. Behind those listings are numerous others, and here all but a few of limited importance and doubtful reliability are listed. I have at least seen all of these sources. Most are in my possession as complete works. Where geyser activity is referred to only within a portion of some much longer work, then I have a copy of the pertinent parts. Only a very small proportion are handwritten (now typed) transcriptions from works located when no duplicating machine was available.

A primary reference not otherwise cited herein is USGS Professional Paper 492, by G.A. Waring. Titled *Thermal Springs of the United States and Other Countries of the World— A Summary,* it contains hundreds of maps and tables and includes an amazing list of 3,733 references. It was here that I got my start. (Do note, however, that this reference is severely dated, and that it is sorely lacking in some respects. For example, the geysers of Kamchatka's Kronotsky Nature Preserve are not noted at all!)

Much of my early research took place at San Diego State University and then at the University of Montana. Further work was accomplished during several visits to the libraries at the University of California, Los Angeles, which sources ultimately produced perhaps one–third of these references. Many, however, were obtained by "non–conventional" means: some works were purchased by mail from agencies and libraries in other nations, such as the Chilean geothermal agency CORFU and the National Library at Canberra, Australia. Also, of course, a number of wonderful geologists overseas directly provided me with copies of their efforts. To all who have helped, my public thank you.

A number of the works are written in some foreign language. Of these, the only ones never translated for me is in Portuguese; but even it includes English summaries! The rest have been translated, either by myself or by a friend or colleague, well enough for the core information to be extracted.

The references here do not include the United States of America. Nor do they cover geothermal works for areas without geysers— this is geyser specific. Some of the citations note that geysers do **not** in fact exist at some spot, but these are as or more important than other earlier publications which **do** note the presence of geysers.

Each reference is annotated with bracketed comments detailing more about the exact location, sometimes with summary information.

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Geyser Eruption Angle, Form, and Frequency as a Function of Geyser Age

by T. Scott Bryan

Abstract

A comparison of the geysers within Dolina Geizerov on the Kamchatka Peninsula of Russia with those in Yellowstone National Park, New Zealand, Iceland, and El Tatio indicates that the angle at which geyser water is erupted and the type of eruption both are functions of how old the geyser is. In each case, the eruption form and attitude is controlled by surface and near-surface geyserite deposits whose development causes evolutionary changes in the geyser performance. In similar fashion, the frequency of a geyser's eruptions can be related to the degree of system "self-sealing", which is again a function of mineral deposition with time.

Introduction

The geysers of Dolina Geizerov (the "Valley of Geysers"), in the Kronotsky Nature Preserve of Russia's Kamchatka Peninsula, are remarkable in a number of ways. They comprise the largest geyser field in the world after Yellowstone, with approximately 200 active geysers. Much of the activity is of major scale. Two of the geysers — Velikan and Grot Yubileinyi— erupt to heights of over 40 meters, and numerous others play in excess of 10 meters high.

Remarkable to experienced observers is the fact that most eruptions in Dolina Geizerov are distinctly angled from the vertical. This applies regardless of the height of the eruption. In many cases, the eruptions are at angles of more than 45° from vertical, and a few are truly horizontal; at least one geyser erupts at a sharp downward angle from a steep slope. The only exceptions to this rule are the few geysers which erupt from distinct geyserite cones.

Nearly all of the Kamchatkan geysers are of the so-called "fountain-type", in which the eruptions consist of discontinuous burstings from a more or less open pool. "Cone-type" geysers, in which the eruptions are continuous jets of water, are uncommon. Most (though not all) of these are restricted to those few features with geyserite cones and, thus, vertical eruptions. There is, therefore, a clear relationship between the angle and form of an eruption and the degree of geyserite formation growth.

As compared to elsewhere, the activity on Kamchatka is intense, the geysers erupting significantly more frequently than do comparable geysers elsewhere. This is true for even the largest of the geysers, where Velikan, with average intervals of barely more than five hours, is demonstrably the least frequent of them all. In a fashion similar to that bearing on eruption form and angle, this frequency can be related to the degree of mineral deposition within the plumbing systems.

The vast majority of geysers in the world's other geyser fields have eruptions that are essentially vertical; angles greater than 10° from the vertical are exceptional. Cone-type geysers are somewhat more abundant than on Kamchatka, but their eruptions also tend to be relatively infrequent. The cause of each of these factors is the volume of mineral deposition within and about the vent and plumbing system of the geyser. In turn, this is dependent on how long the geyser has been active. While it is impossible to place absolute values on the age of such formations, this relationship would appear to be applicable to any occurrence of geysers.

Geyserite and Other Mineral Deposits

As a general rule, geyserite (siliceous sinter) formations form slowly. Comparisons of the modern formations in Yellowstone with photographs taken of them during the early explorations of the park show virtually no change. Individual bumps and fractures are as obvious now as they were 120 years ago, as are acts of vandalism performed during and before the 1870s.

Numerous estimates of surface geyserite deposition rates have been produced through the years. They indicate that most formations grow at rates of less than 2.5 centimeters per century. While there are exceptions, of course, where deposition proceeds at a much greater rate, so too are cases where the deposition is extremely slow. Geyser water contains just a few hundred parts per million of dissolved silica, most of which is carried away with the surface discharge or forms a soft, readily-eroded silica gel along the channels. While we are able to observe little change in human time, the slow geologic growth of the sinter is able to generate considerable, albeit gradual, evolution in the geyser activity. Younger geyser fields should and do exhibit geyser eruptions different from those in older areas.

The pace of mineral deposition at depth within plumbing systems is less well understood, but is generally similarly slow. In this case, geyserite is not a significant portion of the deposit. Instead, numerous other minerals (such as zeolite and other silicates, sulfides, sulfates, and halides) crystallize so as to gradually constrict and even completely seal the plumbing channels. This process of "self-sealing" can eventually isolate a geyser from its water supply, leading to decreased activity, dormancy, and eventual death. Therefore, the frequency of geyser activity within a geyser field should decrease with age.

Geyser Development

There is persuasive evidence that individual geysers are created during earthquakes, phreatic explosions, ground failures, or other "catastrophic" events within existing geothermal fields. Any such event may produce fractures which lead from the surface downward into a geothermal reservoir. These fractures serve as the primary plumbing systems of new hot springs. Which type of spring will result— geyser, pool, mud pot, or fumarole— depends on the volume and temperature of the available water, and the shape of the plumbing.

These new fractures can open to the surface at an angle which is almost invariably something other than vertical. Resulting geyser eruptions must, of course, eject water at an angle corresponding to that of the plumbing.

Eruption Angle vs. Age

Once a geyser has been formed, the flow and spray of its cooling and evaporating water will begin to form new geyserite at the surface. As discharge channels shift, wind and weather patterns change, and the geyser itself enters periodic dormancies, the formations tend to grow more or less equally both within and about all sides of the vent. The vent itself remains open. As progressively more geyserite is laid down, the open crater becomes more vertical in overall aspect. It may also become more constricted.

The eruption obviously must escape through whatever surface opening is available. As that becomes more vertical, so too does the geyser play. The older the geyser, the more vertical its eruption tends to be.

Eruption Type vs. Age

If the geyser vent is also becoming constricted by the near surface formations, it may evolve into a cone-type geyser as well as becoming more vertical. The majority of geysers everywhere are of the fountain-type. Their eruptive force is provided by compressed steam bubbles which rise into and/or exolve from the water within a crater, where they explosively expand. The result is a series of water-steam bursts. If a plumbing system becomes so constricted that an open pool no longer exists, the steam can escape only by ejecting a stream of mixed water-steam through a more restricted opening. Bursting is limited or impossible and the eruption is a steady flow.

The combined result of surface geyserite growth is evolution both from fountain-type to cone-type and from angled to vertical eruptions. Despite their different forms, geysers of the two types are constrained to play with angles and styles controlled by the surface plumbing. Aging geysers tend to achieve more vertical and steadier eruptions. The nature of an eruption is a function of time.

Eruption Frequency vs. Age

It is obvious that no geyser can erupt without a supply of adequately hot water. When plumbing systems are young and there has been little mineral deposition at depth, the geothermal water may freely flow into and through a hot spring. When the size and shape of the plumbing system is "correct" for the water volume and temperature, then the spring may function as a geyser which cycles through its preliminary filling and pressuring stages fairly quickly. The geyser has frequent eruptions.

In time, mineral deposition accumulates and progressively limits the volume of water flow into the plumbing system. This is called self–sealing. What water is available may be able to cool via heat conduction into the surrounding rock and by convection and evaporation at the surface of whatever opening exists. This energy loss can be efficient enough to reduce the need for explosive, eruptive stabilization. Eruptions become less frequent with the passage of time and may eventually cease entirely.

There are apparent secondary importances to self-sealing, largely beyond the the aim of this paper. Although it is bound to reduce the frequency of geyser eruptions, self-sealing can also increase the sheer number of geysers within a geothermal area. It forces high-temperature water to pool at depth beneath the self-sealed zone (which in Yellowstone typically lies about 200 feet from the surface). This store of water, under pressure, must in time escape via whatever route is available. Often it is distributed among many lesser springs. Any geysers will only rarely erupt, producing those brief and unpredictable spectacles so dear to dedicated geyser observers. Yellowstone contains more geysers than any other comparable geothermal area on Earth because of extensive self–sealing overpressures within its major geyser basins.

Self-sealing might also be a prime cause of exchange of function. This is the shift of energy from one geyser or spring (individual or as a group) to another. Exchange of function can be abrupt or gradual and it can be recurring or unique, but in any case could be a result of changing water flow patterns at depth because of self-sealing developments. It is notable that the concept of exchange of function was a new and rather shocking idea to the Russians.

Kamchatka vs. Elsewhere

As noted, geyser eruptions within Dolina Geizerov are dominantly of the fountain-type and/or played at angles considerably other than vertical. Several of the geysers show angles of less than 45°. Such angles are extremely rare elsewhere. In fact, only two known geysers of size— Yellowstone's Ledge and Fan— have such acute jets.

The Kamchatkan geysers also erupt with extraordinary frequency for their size. Eruption intervals longer than one hour are uncommon, and those of many hours essentially unknown.

These factors set Dolina Geizerov aside as distinctly different from the world's other major geyser fields. However, the cause is clear. An examination of the Kamchatka geyserites shows them to be little more than thin coatings on boulders and ground surfaces. Even on the most extensive terraces the thickness is seldom more than a few centimeters. The geyser vents are little more than original fractures penetrating the ground, without alteration by subsequent mineral deposition.

Why this has happened in Dolina Geizerov whereas other geyser fields include geyserite deposits as much as 6 meters thick is clear. The other areas occupy gentle valleys. Dolina Geizerov is within a deep canyon. The Geizernaya River flows at a gradient of about 150 meters per kilometer (nearly 800 feet per mile). It is often muddy and cuts its channel downward at a geologically rapid rate. New fractures which serve as new hot spring and geyser vents are constantly being opened. Their activity taps into the water supplies of older springs, which are now perched higher on the canyon walls. In keeping with this, nearly all of these geysers are located in the bottom of the canyon. Most of the springs at higher elevations are reduced to mud pots and a few quiet pools and fumaroles of relatively low temperatures.

Via this process, too, the existing springs are seldom granted the time to grow thick geyserite formations. During their geologically brief existences, the geysers do not have the opportunity to evolve into the vertical and cone-type geysers commonly seen elsewhere, where erosional rates are lower and individual geyser lifetimes longer.

Most of the cone-type geysers that do exist are of small size and can be shown to be of the cone-type because of narrow fracture vents surrounded by young, small volume cones.

The Kamchatkan geysers have not been significantly self-sealed, either. Their activity is of high frequency due to a highly free flow of subsurface water.

By contrast, places like Yellowstone have had adequate time for thick geyserite terraces and cones to form. Few geysers have the angled eruptions that are so common on Kamchatka. Most of those that do can be shown to be relatively young features.

Conclusion

The geysers of Dolina Geizerov provide a model of the development of geyser form, type, and frequency as a function of age. These factors change as individual geysers grow older— the relative proportions of vertical and cone-type eruptions increase while eruption frequency decreases as a geyser field ages.

There should be application of this rule within any geyser field, and since many other aspects of a geothermal system change with time, this simple observation of surface activity may have deeper implications.

Acknowledgements
Many of the thoughts expressed in this paper were stimulated by Drs. Donald E. White and Robert O. Fournier, of the U.S. Geological Survey; some input was also given by Dr. Terry Keith, also of the USGS. To them, my thanks for taking the time for these discussions.

Annual Basin–Wide Disturbances Along the Firehole River
A Very Speculative Thought

by T. Scott Bryan

Abstract

Annual "basin-wide disturbances" are well documented for the Norris Geyser Basin, but have generally received only passing discussion as a possibility in other areas of Yellowstone and elsewhere. However, a long-standing rule of thumb has been that the late summer season is the time most likely to see rare unpredictable eruptions and large-scale changes in Yellowstone geyser basins other than Norris. Perhaps this is because of a similar effect. Observations during August, 1986 provide evidence for such a disturbance within the geyser basins along the Firehole River.

Late Season Disturbances

The fact that basin-wide disturbances in geyser and other geothermal activity occur annually at the Norris Geyser Basin in Yellowstone is well established. It has been explained in essence as occurring because of a near-surface overpressuring within the geothermal regime due to rising deep fluids mixing with a second, shallower fluid. The disturbances are most commonly noted relatively late in the summer season as that is the time when there is the greatest degree of change in the near-surface fluids: a decrease in surface volumes combined with partial self-sealing within plumbing systems leads to hydrofracturing and an upwards surge of hotter, deeper water [White and others, 1988]. The result is a series of radical behavior changes among the hot springs. At times the effect is basin-wide and involves dozens of springs; on other occasions the disturbance is less intense and can be noticed only by experienced observers within a more restricted portion of the geyser basin.

These disturbances are usually taken as being unique to Norris, and that is nearly so whether the evidence presented here is valid or not. Norris is the only significantly sized acidic thermal area of its sort anywhere. Its waters carry large amounts of dissolved and solid mineral matter which is readily deposited so as to clog near-surface plumbing channels. That much change takes place at Norris is easy to understand.

However, a similar mixing of deep with shallow fluids is likely to occur in any geyser basin. White [1968] found evidence for seasonal changes at the Steamboat Hot Springs, Nevada. Informal users of springs in California's Long Valley caldera have reported turbidity and higher temperatures during the autumn months of each year [Bryan, 1991]. There is a hint of seasonal activity changes involving the geyser at Mickey Hot Springs, Oregon, although they might result from surface (ground water) conditions [miscellaneous personal communications]. On the other hand, Keam [1990] reports that no form of seasonal disturbance activity change has ever been observed in any of the New Zealand thermal areas, which statement was repeated by Nikolayenko [1991] on Kamchatka.

In the Firehole River Geyser Basins (that is, the Upper, Midway and Lower Basins), it has long been observed that late summer and early fall are the time of each year when unusual events are most likely to occur. Two notable, recent examples of this have been the October 1985 activity by Excelsior Geyser (Midway Geyser Basin) and the series of August-September-October eruptions by Giant Geyser (Upper Basin) that started in 1978 prior to the current (1988-1992) cycle of hot period and eruptive activity.

Observed Activity Changes of August 20-24, 1986

Beyond occasional events such as those just noted, hard evidence of true basin-wide disturbances in these geyser basins has not been noted. Although still strictly observational, and probably subject to alternate interpretations, a series of events which took place during August 20-24, 1986 might have been just such a case. The following is a day-to-day description of this episode:

<u>August 20</u>

•Giant Geyser erupted at 11:36. As had been the case with the eruptions in 1978, 1982, and 1984, this eruption began without known precursor activity by associated geysers and vents, and without any observed increase in surging by Giant itself.

•Shortly after the eruption by Giant, Oblong Geyser underwent its third-ever recorded episode of short interval eruptions, the second interval being only 28 minutes.

•After a season of remarkably regular eruptions and intervals, on this date Fantail Geyser abruptly began an episode of longer and extremely erratic intervals. In addition, the force of the eruptions became notably less, and activity nearly ceased in nearby

Ouzel Geyser.

•Opal Pool, in the Midway Basin, underwent a remarkable series of powerful eruptions, with perhaps more bursts recorded in that single day than in any similar time span previously recorded.

August 21

•Splendid Geyser, although active earlier in the season, began its first "good" activity, having a series of eruptions on intervals of 1 to 3 hours. Once started, this action continued through the remainder of the 1986 season.

•On Geyser Hill, Aurum Geyser overflowed heavily without eruption for something longer than two hours. Simultaneously, Ear Spring underwent a series of brief, bursting eruptions about 2 feet high. This episode ended with an extraordinarily powerful eruption of Aurum, followed by second full-force, full-duration eruption less than two minutes later.

August 22

•Grand Geyser, which had had average intervals of about 9 hours, abruptly increased its intervals to an average of near 10 hours and then, in the succeeding few days, further increased to fully 11 hours. This was accompanied by an increase in eruption frequency by West Triplet and Rift Geysers.

August 23

•Riverside Geyser had a series of at least three consecutive short-mode intervals, each of which was shorter than any but one other short mode interval seen earlier during the entire year.

•Cauliflower Geyser began a series of frequent major eruptions (up to 60 feet high), which persisted for several weeks following.

•Fantail Geyser entered an episode of weak, short duration-short interval eruptions which lacked the concluding steam phase of the previous eruptions. This action persisted for most the the remainder of its activity cycle, which ended in October.

•Fountain Geyser (Lower Basin) had two eruptions separated by an interval of only 3 1/2 hours. The first of these had a normal (50 minute) duration and was said by observers to have easily reached 100 feet high; the second had a duration of fully 2 1/2 hours consisting of nearly continuous 25-foot bursts.

•Jelly Spring followed the eruptions of Fountain with its first known eruptions of 1986.

•Box Spring (Lower Basin) reactivitated after a short dormancy, having two observed eruptions.

August 24

•Riverside Geyser had two well-documented eruptions which were extremely powerful (one's water completely spanned the river) and which ended with noisy, roaring steam-phase activity; the durations of both eruptions were in excess of 27 minutes (versus the nearly invariable 21±1 minutes which is normal).

•Beehive Geyser played for the first time since August 20, after an interval of exactly 89 hours. Although Beehive had been showing a tendency toward longer and more erratic intervals, this was incomparably the longest of 1986. Prior to this eruption, all three of Beehive's indicator vents were active— these included the well-known Beehive's Indicator, the "second" indicator whose vent is between the cone and the Indicator, and a third vent about 20 feet west of the cone.

Conclusion

It is not the purpose of this paper to provide an explanation for these events. The 1986 season was unusual in many respects and was among the very best "geyser gazing" seasons of the past two decades. However, the dramatic changes and cases of unusual performances which began on August 20, 1986 appears to be without recorded precedent, and might well be taken as an indication of basin-wide disturbance action affecting the geyser basins along the Firehole River.

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GOSA

GOSA Transactions
Volume III, 1992

The Geyser Observation and Study Association

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