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Hydrothermal Observations In Yellowstone National Park 1988

Upper Geyser Basin
Lower Geyser Basin
Lone Star Geyser Basin
Norris Geyser Basin
Monument Geyser Basin

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PREFACE

This report summarizes my observations from April 26 through November 15, 1988, of geyser and hot spring activity in Yellowstone National Park. The areas of study included the following geyser basins:

Upper Geyser Basin
Lower Geyser Basin
Lone Star Geyser Basin
Norris Geyser Basin
Monument Geyser Basin

This year's report includes the first extensive and revealing observations of the Giant/Grotto Group in over 30 years.

The observations and this report were the primary objectives of my employment as a Physical Science Technician under the direction of Rick Hutchinson, Research Geologist for Yellowstone National Park's Division of research.

Some clock times are abbreviated throughout the report. Abbreviations used include:

y - years
d - days
h - hours
m - minutes
s - seconds

Two earthquakes are referred to in the text. The 1959 earthquake is the Hebgen Lake, Montana earthquake of 1959. The 1983 earthquake is the Borah Peak, Idaho, earthquake of 1983.

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I thank all the visitors, Park Service naturalists, maintenance personnel, and rangers who provided information which furthered the understanding of the hydrothermal features presented in this year's report. Thanks, Rick, for giving me free reign to study those features I felt were appropriate at the time. Thanks, Marjorie, for typing all this.

The wealth of data collected on this year's activities, especially those of the Giant/Grotto Group, was made possible only with the careful, dedicated observations made by the following thermal observers.

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BLACK HOLE GEYSER

This geyser's funnel-shaped vent is located 5 feet southwest of Perforated Cone Geyser and 22 feet feet northeast of the center of Lone Star's Cone. the geyser's clear pool was usually below overflow. Occasional individual bubbles rose to break the otherwise calm pool. Fluctuations in the pool's level were in response to unknown conditions underground. Graphs on pages 210 & 211 show that Black Hole's pool level was "up" during some of Lone Star's active periods, and descending during others. Also note Black Hole's pool remained "up" for over 2 hours before one of its eruptions. On another occasion the pool rose only minutes prior to an eruption, and then remained up for 2 hours shortly after the eruption.

Eruptions began from an overflowing or nearly overflowing pool. Heights of the constant outpour quickly reached 2 - 3 feet. Taller spits reached out of the smaller eruption to 10 - 12 feet. Eruptions were a constant liquid output that decreased in height to become a strong boil, which from a distance looked like a strong steam phase. I noted the end of an eruption as the time when the pool level began to rise from its lowest point, which was about 2 1/2 feet below overflow. The strength of the boiling decreased slightly during the initial rise of the pools' level. The boiling was much decreased by the time the pool's level was 1 - 1 1/2 feet below rim top. At this time there were only occasional bubbles produced, which later stopped. The pool would then fluctuate up and down. Occasional periods of bubbling occurred. At other times the water was cool enough to immerse your entire arm in. Eruption durations averaged 22m 38s and one interval of 9h 48m was observed (Fig. 1, Pg. 208).

The extremely variable activity in Black Hole Geyser implies connections exist between this geyser and others. Black Hole's location suggests

connections in itself. I did not observe enough consistent trends to say that the geyser was absolutely related to Lone Star or Perforated Cone Geysers.

Last year's durations varied from 3 - 15 minutes and intervals from 2 1/2 - 5 1/2 hours (Landis, pg. 66); thus this year's activity is less than last year's. Eruptions of a feature near Lone Star reached 15 feet in 1973 (Marler, pg. 352). This sounds very much like Black Hole Geyser.

LONE STAR GEYSER

The geyser was completely calm about 70 minutes prior to an eruption. At this time trickle flow occurred from a small vent 1/3 the way up the west-southwest side of Lone Star's cone. This small vent I call the west vent. The west vent's flow rate served as an excellent indicator as to the progression of Lone Star's interval. If the vent's flow increased, then an eruption was soon to come. Lone Star produced occasional inner-vent rumbles about one hour prior to an eruption. Visible splashes reached out of the cone about 45 - 60 minutes prior to an eruption. These first splashes usually did not pour water out of the cone, though later splashes almost always did. At this same time the west vent's outpour would have increased from a trickle to the point where it was just starting to clear the cone's wall. Lone Star's pre-eruptive bursts lasted 5 - 10 seconds and reached about 3 - 6 feet above the cone 15-30 minutes prior to an eruption. More rumbling occurred between these outpours. The west vent's outpour cleared the entire vertical drop of the cone (about 3 - 4 feet) 30 - 40 minutes prior to an eruption, and continued to do so up to and throughout Lone Star's eruption.

Eruptions finally began with an extended outpour about 1 - 3 feet in height for 30 - 60 seconds leading up to the true eruption. I began eruptions when the water column climbed above this outpour condition, since some extended outpours did not materialize into anything besides a wet cone. The liquid outpour finally increased to 20 - 30 feet above ground within the first minute of an eruption. Heights of 30 - 40 feet were noted during the first 90 seconds of an eruption. Occasional near-pauses in activity sometimes occurred, as if the geyser couldn't decide between a major or a minor eruption. Liquid phases lasted about 6 - 10 minutes, and were followed by a strong, roaring steam phase. Initial liquid spray during the liquid-steam transition reached measured heights of 50 - 58 feet above ground level (base of cone). Steam phases maintained their strength for about 10 minutes; after which pulses in output were noted. I noted the end of an eruption when the first

pause in the steam phase's then billowing output occurred. Additional steam pulses occurred after this time for about another 4 - 6 minutes; with each separated by 10 - 20 seconds of calm. Finally no more steam pulses occurred and the west vent's outpour had reduced to running down the side of the cone. The cone was quiet and the west vent producing just visible trickle flow about 40 - 60 minutes after an eruption. The west vent's flow rate picked up about the time Lone Star produced its first rumble leading up to the next eruption.

Eruption durations averaged 24m 11s and intervals averaged 2h 49m (Fig. 1 & 4, pg. 209). No minor eruptions occurred between most of this year's major eruptions of Lone Star (Fig. 3, pg. 209). Note that on one occasion two minors occurred between majors. Minor eruptions began jut like majors with an extended outpour cumulating with a climbing water column to 20 - 30 feet above ground. The water column would suddenly stop, followed by about 15 minutes of calm before rumbling occurred again. The average minor eruption duration was 3m 12s (Fig. 2, pg. 209). Lone Star's intervals were shorter if minors occurred, than if no minors occurred. One interval of 24 minutes occurred between minors. Minors preceded majors by 21, 37, and 46 minutes during this year's observations.

Lone Star's eruptions are compared to Black Hole's activity and Perforated Cones eruptions on pages 210 & 211. No definite connection exists between Lone Star and Black Hole. Note that every long eruption of Perforated Cone overlaps with eruptions of Lone Star, or occurs prior to Lone Star's activity. More observations would help support a very possible connection between these two features.

Lone Star did not appear to be affected by the August 24 earthquake located in the immediate vicinity of the geyser, though no observations were made immediately after the earthquake. This year's average eruption duration was shorter than last year's by about 2 minutes, with the shortest this year a full 3 minutes shorter than last year's shortest (Landis, pg. 67). This year's average interval was much the same as last year. Minor eruption durations were about the same both years. This year's large proportion of major eruptions without minors in between suggests a trend away from the minor eruption followed by a major eruption noted in Marler's report (Marler, pg. 351). Otherwise intervals remain consistent with past observations.

"PERFORATED CONE" GEYSER

Perforated Cone Geyser is located 27 feet northeast of the center of Lone Star's cone, and 5 feet northeast of Black Hole Geyser. Observations of this geyser were best made by sitting within a few feet of the geyser, though staying out of the way of Lone Star's splashing proved to be difficult. Runoff trickled out of the base of the cone between 10 & 15 minutes prior to an eruption. Eruptions began with 2 - 4 inch spitting from numerous locations on the geyser's mound. Other locations only produced surface sizzling. Occasional spikes reached about one foot above the cone. Eruptive strength fluctuated with a pulsing action, though no pauses in activity occurred. Water surged from locations halfway up the cone about 5 - 10 minutes into some of the longer eruptions. Water expelled by eruptions was very hot, burning the skin instantly. Water flow from the cone's base occurred throughout eruptions and generally ended 2 - 3 minutes after an eruption ended. An eruption's sizzle could be heard about 80 feet away. Sizzling died down and finally stopped to mark the end of an eruption.

Eruption durations varied from 1m 30s to almost 64 minutes, with an average duration of 31m 25s (Fig. 3, pg. 208). Eruption intervals averaged 2h 10m. A noted overlap occurred between Perforated Cone's eruptions and eruptions of Lone Star Geyser (Pages 210 & 211). Note here that Perforated Cone's eruptions begin prior to Lone Star's eruptions and generally continued through the latter's eruptions. Close, wet observations were required to collect this data. Most of this data would hot have been possible to collect at a distance of 50 feet from the area, due to the size of the eruptions. I believe the overlap of the two geyser's eruptions suggests a very probable relationship between the two features. Last year's data scatter (Landis, pg. 69) promoted this year's closer and more extensive observations.

CLIFF GEYSER

A calm period followed an eruption for about six minutes, during which the geyser's pool was out of view when observed from the boardwalk across the creek from Cliff. Individual 3 - 4 foot bursts from an empty pool occurred about 10 - 12 minutes prior to an eruption. These bursts lasted only a few seconds. The height and durations of the bursts continued to increase as an eruption neared. Bursts reached over 10 feet in height and lasted 15 - 20 seconds about five minutes before an eruption.

A constant eruption finally began with 10 - 20 foot bursts from a still-out-of-view pool level, or a pool level about 1 - 2 feet below rim top. The geyser's pool level was always in view from 1 - 3 minutes into an eruption, though about three minutes was most common. Cliff's eruptions included some periods of constant, almost vigorous play, though play usually consisted of individual (though close together) bursts, with all activity from a full pool during the last 75% of an eruption. Many individual bursts were separated by 2 - 5 second pauses, and commonly reached heights of 15 - 20 feet, though occasionally 20 - 30 feet. A noted pause in activity of about 30 seconds duration marked the end of an eruption. The geyser's pool level drained out of view about 30 seconds after an eruption ended. A calm period of about six minutes followed an eruption.

Eruption durations and intervals averaged 14m and 32m respectively (Fig. 1 & 2, pg. 212). Two minor eruptions occurred during one major eruption interval. Durations of these minors were 23 and 65 seconds (Fig. 3, pg 212). Intervals between the minors and the preceding major were 32m and 35m, with a 2m 40s interval between the minors. A major eruption followed 3m 10s after the second minor. Minors were characterized by nearly constant bursting from an out-of-view pool.

Last year's average duration and interval (12m and 34m) were much the same as this year's average (Landis, pg. 5). Many minors lasting 1 - 5 minutes were noted last year; thus there was a notable decrease in minor activity this year.

Cliff's activity over the last two years is a major change in its behavior over the last 60 years. One or two eruptions per day were noted during the 1930's, 40's, and 50's (Marler, pg. 333). Eruptions during the 1960's occurred 1 or 2 times a day and lasted about 3 hours. During the late 1960's, eruptions were beginning to occur erratically from low and high pool levels. The past activity by Cliff Geyser is very much like the present activity of Spouter Geyser.

HANDKERCHIEF POOL

The pool's surface always exhibited pulsing and bubbling. John Railey supplied a handkerchief for the purpose of ascertaining whether or not the pool still drew pieces of cloth down out of view, and then returned them clean.

At the surface, the pool was bordered by brown algae on the east and west. To the north the pool received runoff from springs upstream via an orange runoff channel. To the south the pool supplied a constant outflow to a grey runoff channel. The pool itself was clear. Large patches of orange algae lay at each side of the entrance to the pool's grey southern runoff channel, and a rim of orange algae surrounded the main pool, as well as extending north of the pool as previously noted. The pool's bowl was grey sinter, with the main vent located in the center of the grey bowl. Numerous bubbling vents were located in the pool's grey sinter bowl and also in the grey runoff channel located south of the pool's main vent. The main vent has an hour-glass shape, with a constriction located about 1 - 1 1/2 feet below the pool's surface.

Numerous locations were tried to determine the best place for submergence of the hanky. A location west-southwest of the pool's main vent worked best. The hanky was occasionally pushed around by convection cells within the pool, only to remain above the constriction mentioned earlier. Balling up the hanky proved helpful in promoting the submergence of the hanky to the area below the constriction. The hanky always rose to the east of the main vent, whether or not it was drawn below the constriction. The hanky began its descent slowly down the west-southwest wall of the vent. Sometimes the hanky was caught in the vent's upward currents which produced the pool surface pulsing and bubbling. Once the hanky was caught in the upward current, it was quickly expelled to the pool's eastern rim. On other occasions

the hanky continued its slow descent down the wall of the vent, toward the constriction. Stronger venturi effects sped up the downward motion of the hanky as it passed through the venturi of the hour glass shaped vent. The hanky would literally shoot through the constriction and disappear. Once the hanky was below the constriction it either remained out of sight until upward forces sent it back through the venturi, or it was swirled round and round as if in a washing machine. At this time the hanky would be drawn out lengthwise in an arc-shape, swirling a complete circle in under two seconds. Eventually the hanky would be caught by upward forces and shot upward through the constriction to surface immediately in the pool's eastern quadrant. Overall, the hanky descended in about 4 - 6 seconds, and ascended in about two seconds. The overall average submergence time (below the pool's surface) was 14 seconds. If the hanky made it through the constriction, then the time of submergence averaged 17 seconds (Fig. 3, pg 213). After the experiment, John said his hanky needed another group of washings to really clean it.

One visitor this summer said that in 1928, the hanky stayed submerged about 1 - 1 1/2 minutes. The pool's activity has changed over the years, probably due to the amount of vandalism it has received. In 1888, the pool's water evidently sucked down out of view and then gushed back out several minutes later (Whittlesey, pg. 70). By 1929 the pool was choked with garbage thrown in by park visitors and ceased to function (Marler, pg. 339). Eruptions of Rainbow Pool in 1938 filled in what remained of the pool so no sign of it was evident. George Marler must be credited with an excellent job of cleaning all the debris out of the pool in 1950 including a six foot long piece of lodge pole pine that had been driven down the pool's main vent, which lies below the hour-glass constriction. His description located this vent at the east side of the bottom of the pool, which corresponds with the present rise of handkerchiefs to the east side of the pool's surface. I'm glad there are no signs or incentive (except memory) for visitors to see this unique feature. This approach seems to be the only way to preserve the park's hydrothermal features.

RAINBOW POOL

No bubbling or boiling attracted my attention this year or last. The pool exhibited constant overflow to the south during both year's observations. The clear pool's runoff supported extensive algae beds.

The pool has been in overflow for most of its history. In 1938 numerous eruptions were observed; comprised of individual 50 - 80 foot bursts with a total duration of activity between 5 & 10 minutes. Weaker activity followed in 1939, and 1947. In 1948 strong bursts like those in 1938 occurred. This was the pool's last observed eruptive activity. The 1959 earthquake reduced the pool's overflow, but by 1969 overflow had reinstated itself. The pool's current overflow may imply that eruptions may be observed again someday.

"REFRACTED" GEYSER

I suggest this non-traditional name for a small spouter located about 130 feet south of the center of Rainbow Pool. See the map in my notes on page 309. The name is derived from the names of nearby features such that while standing with the sunset to your back (Sunset Lake), the observer looks out to see a rainbow (Rainbow Pool). Beyond the rainbow is a second smaller rainbow formed by the refraction of the Sunset's light. This second smaller "rainbow" is the small spouter I'm about to describe; otherwise known as Refracted Geyser.

The geyser was not observed erupting last year, but has been seen in the past. Activity between this year's eruptions never truly stopped. The geyser was the least active about 20 minutes after the end of an eruption, which corresponds to about 55 minutes before the next eruption. At this time there was 1/2 inch bubbling from a clear pool whose level was about one inch below overflow. Within five minutes of this time the geyser's pool would overflow its rim. Minute ripples of overflow occurred over the next 10 minutes or so, along with a slight increase in the geyser's runoff which wetted an area of about 2 yards diameter. The geyser's bubbling had increased to about one inch in height about 20 minutes before an eruption; and overflow continued. Bubbling was 1 - 4 inches high about 10 minutes prior to an eruption, with 1 - 6 inch constant bubbling occurring about 5 minutes before an eruption. Eruptions began at a time when the geyser's activity quickly picked up to include 4 - 6 inch constant audible bubbling intermixed with occasional 5 - 15 inch bursts. Intermittent bursts reached about 2 feet in height four minutes into an eruption, and soon after reached 3 - 8 feet in height. The overall play was only 2 - 3 feet high about six minutes into an eruption. Eruptive strength began decreasing about 10 minutes into an eruption, with 1 - 2 foot bursts at best. Brief one second pauses between 4 - 8 inch bursts were noted 30 minute into an eruption. The geyser's pool level would be 4 - 6 inches below rim top at this time. The

pauses finally increased to 2 or more seconds with bursts reaching only 2 - 4 inches in height. I noted this time as the end of an eruption. Within 5 - 10 minutes of this time only one inch bubbling was produced from a pool level about four inches below overflow. As noted earlier, the geyser's pool level then slowly rose to overflow prior to any increase in the strength of bubbling. Eruption durations and intervals averaged about 36m and 1h 51m respectively (Fig. 2 & 3, pg 214). Marler makes no reference to this geyser as of 1970, when he compiled his notes.

SPOUTER GEYSER

One complete eruption was observed this summer. The eruption began with individual and overlapping 1/2 - 3 foot boils. A small vent about 10 - 15 feet south of Spouter was also active with 1/2 - 1 foot spits. This south vent produced mostly steam, seven minutes into Spouter's eruption. Spouter continued producing a 1 - 2 foot rolling boil about 40 minutes into an eruption, with occasional 4 - 8 foot boils. Bursts and boils seem to come from several locations within the geyser's vent, as if there were several underground openings leading to one main surface vent. Most bursts were expelled vertically, and some to the south. Sometimes only surface boiling occurred in the geyser's pool. Eruptions had a pronounced end to their activity.

One 1h 56m duration was observed followed by one 4h 5m interval. Last year's durations and intervals averaged 3h 20m and 5h 57m respectively, thus this year's durations and intervals were notably shorter than last years. (Landis, pg. 7). This year's shorter eruptions involved 72% of an interval whereas last year's longer durations involved only 56% of an interval. Note that longer durations were followed by a longer quiet period during which the geyser "recharged" itself. This relationship may imply that intervals follow a relatively simple I - f(d) relationship where "I" is the interval and "d" is the duration.

The last two year's eruptive pattern is a decline in activity from that which was observed prior to 1970. Eruptions then were nearly continuous, with one or more 2 hour quiet periods occurring each day (Marler, pg. 342). Note that Cliff and Spouter were more active before 1970, than they are now.

SUNSET LAKE

Constant overflow from a clear pool occurred during all observations this year and last year. This runoff supported extensive algae beds. Eruptive bursts continued to occur this year, and were observed last year. Occasional periods of increased activity were noted. Bursts varied in height from 3 - 12 feet or more. Some bursts climbed up like a large thumb rising out of the lake, other bursts were more dome-shaped and were clearly audible (from near Handkerchief Pool) as they crashed back into the lake. Some bursts were more like large boils. Either burst form was an excellent background for Rainbow Lake's calm pool. The durations and intervals of Sunset's bursts averaged 13s and 2m respectively (Fig. 1 & 2, pg 213). No changes in the activity of nearby spouters or geysers seemed related to Sunset's activity.

The present eruptive activity is consistent with occasional "minor activity" observed since the 1959 earthquake (Marler, pg. 343). The Earthquake caused a major eruption in Sunset Lake, after which several months passed before overflow resumed.

WHISTLE GEYSER

Light steam was visible spewing from the geyser's vent on cool mornings. No other activity was noted this year or last. A small murky pool was also noted several inches below rim top. Infrequent eruptions have occurred in the past, amounting to 20 observed eruptions in about 100 years (Whittlesey, pg. 165). Eruptions produced a stream of water to 30 - 40 feet, and forced steam to over 100 feet. The eruption's whistle-like roar was audible half a mile away. Eruptions last 2 - 3 hours, discharging water during only the first few minutes. The majority of my studies occurred in the Upper Geyser Basin last year and this year. If Whistle Geyser can be heard half a mile away, I'm sure I would have heard it.

JEWEL GEYSER

The geyser's pool level rose 3 - 5 inches prior to an eruption. Visible bubbling occurred about two minutes before an eruption. The pool's surface pulsed about 10 seconds before an eruption, along with a pool level rise of about one more inch. Eruptions consisted usually of a group of individual bursts, with the initial burst reaching 3 - 10 feet in height. Each burst lasted 3 - 5 seconds, and there were usually three burst per eruption (Fig. 2, pg 215). Pauses between bursts lasted about 10 - 15 seconds. The taller bursts angled slightly to the west with a feather-like shape. Occasional domed bursts reached over eight feet in height. Following the last burst of an eruption, bubbling continued for another 15 - 20 seconds. The pool level would be down 4 - 6 inches from its high point about one minute after an eruption. The pool was calm at this time. The pool level slowly rose prior to the next eruption.

The average eruption duration was 23 seconds (Fig. 1, pg. 215), and average interval was 9 minutes (Fig. 3, pg 215). The interval scatter implies connections exist between Jewel and other features in the area, though no positive or suggestive connections were observed.

Eruption durations were longer last year (35s) and intervals shorter (8m) than this year (Landis, pg. 1). The geyser was originally named "Soda Geyser" by the Hayden expedition of 1871 (Whittlesey, pg. 104; Marler, pg. 21). Eruptions at that time occurred every 10 minutes and reached heights of 10 feet. Recorded activity since then has been very similar to the present activity, except for six years of semi-continuous activity following the 1959 earthquake (Marler, pg. 21).

MUSTARD SPRING

Eruptions occurred from the east spring. The spring's pool remained about two feet down between eruptions, and eruptions began at this low pool level. Eruptions were at first intermittent bursts. The pool filled during the first 1 - 2 minutes of an eruption almost to the point of overflow; though runoff did not occur. Bursts generally reached 1 - 4 feet. Eruption intensity decreased during the last 30 seconds of an eruption. The spring's pool level began dropping as soon as an eruption ended. Occasional bubbles were produced as the pool level dropped.

Eruption durations averaged 4m 50s and intervals averaged 8m 48s (Fig. 1 & 2, pg 216). Eruption durations and intervals were close to last year's activity (Landis, pg. 2). This year no activity was observed from pools in the area north of Mustard Spring, though last year I observed occasional bursts under four feet high from a location north of East Mustard Spring. No eruptions were observed in either of Mustard's two springs prior to 1970 (Marler, pg. 19). The 1959 earthquake induced boiling in both the springs.

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RUSTY GEYSER

Occasional 2 - 3 inch bubbling occurred about 10 seconds prior to an eruption. Eruptions occurred from a non-visible pool, and no pre-eruptive overflow occurred. Eruptions required about five seconds to build to a full height of 2 - 4 feet. Maximum height was maintained for 5 - 15 seconds, after which the eruption's strength lessened over about five seconds time. Water rose to about 2 - 3 inches below overflow during an eruption. Eruption durations and intervals averaged 15s and 49s respectively (Fig. 1 & 2, pg 217).

This year's averages were close to those noted last year (Landis, pg. 3). Past eruptions occurred simultaneously from two vents (Marler, pg. 25). Following a rejuvenation in 1968, only one vent has played.

SAPPHIRE POOL

Constant overflow to the south occurred from the clear pool. No bubbles were observed. The large sheets of sinter which were thrown out by past eruptions have been weathered into virtual non-existence. Many large blocks of sinter remain in the bottom of the pool; much like Cascade Geyser. Runoff from the pool has evidently killed a group of trees south of the pool. Sinter ledges below the pool's surface are covered with pennies and other garbage. If an observer stands where the pool's trash cannot be seen, Sapphire's deep-blue pool stands out as one of the most beautiful in the Old Faithful area.

The pool was named for "the color of its water" between 1883 & 1886 (Whittlesey, pg. 135). At that time only overflow was observed. Increasing degrees of boiling (to 3 - 4 feet) occurred from 1927 through the early 1950's (Marler, pg. 26). A possible soap-induced eruption occurred in 1955. The 1959 earthquake transformed Sapphire into a major geyser with eruptions occurring every 1 - 2 hours, reaching 100 - 150 feet in height, and up to 250 feet wide. These major eruptions continued through 1961, followed by a slow decline in strength until the last true eruptions were observed in 1968. The strength of the eruptions tore huge pieces of sinter out of the geyser's rim, thus destroying the original natural biscuits which the area was named for. The geyser tore its plumbing system apart enough to end all eruptive behavior, much like Excelsior Geyser.

SHELL GEYSER

No periods of boiling overflow were observed this year. The spring's pool level remained about 3 - 4 feet down with constant boiling. Occasional stronger 1 - 3 foot splashing was observed. Last year's activity included approximate 15 minute periods of boiling about 30 minutes apart (Landis, pg. 4). These boiling periods included runoff to an eastern runoff channel. The periods of boiling I noted last year were considered eruptions by past observers (Marler, pg. 35). No early references to the present day near-dormancy were noted.

ANEMONE GEYSER GROUP

Anemone Geyser is located about two yards north of Little Anemone Geyser. Both geysers remained empty of water between eruptions. About five seconds prior to an eruption, Anemone would fill with water to the point of overflowings its basin. A steady eruption would quickly build to 4 - 8 feet in height, with much water splattered about as the eruption progressed. Eruptions dropped from full height to a full pool in about 5 seconds. The pool then drained in about another 5 seconds with a strong sucking sound. Little Anemone generally erupted 70 seconds later (if it erupted at all) with a form very much like Anemone Geyser, except the height reached only 2 - 3 feet.

The average duration for Anemone fluctuated considerably this summer, unlike the summer of 1987 where eruptive activity was very consistent. This year there was a change in late May/early June from consistent to erratic behavior. Prior to June, the average duration and interval was 36s and 7m 7s respectively (Fig. 1 & 3, pg. 218). After early June, Anemone's durations shortened to an average of 29s and the intervals became widely scattered with an average of 8m 17s (Fig. 2 & 4, pg. 218). This change in Anemone's activity coincided with an increase in the durations of Little Anemone's eruptions from 18s before June to 3m15s after June (Fig. 2 & 4, pg. 219). As noted in Figure 4, one eruption of Little Anemone lasted 12 minutes. Examples of erratic behavior are shown in Fig. 1 & 2, pg. 220. No readily apparent changes in activity were noted during eruptions by Giantess Geyser.

Eruptive activity prior to June of this year was much the same as activity noted last year. Last year's data includes (Landis, pg. 8):

Anemone duration	37 s
interval	6m 55s
Little Anemone duration	22s
Time Little Anemone started after Anemone	89s

The present activity is similar to that in the 1950's where Anemone's intervals were about 10 min. (Marler, pg. 270). Between the 1920's-1950's, intervals were about 20 minutes. The 1950 earthquake caused Little Anemone to erupt constantly (Anemone was dormant) until 1961 when a slow shift back to activity in both geysers began. Note that this year's non-earthquake related activity is somewhat like that which occurred following the 1959 earthquake. The original third (northernmost) vent remains filled in with sinter debris and has not been active since the 1959 earthquake. The strength of eruptions increased following the 1983 earthquake (Hutchinson, pg. 614). At present water is still ejected onto the boardwalk.

ARROWHEAD SPRING

The spring remained in constant overflow during every observation this summer. Overflow amounted to a trickle and was primarily to the south. The pool was always clear, with an occasional individual bubble seen. Pool level fluctuations were at most about 1/4 inch. One or more surges of overflow (or eruptions) occurred between May 21 and 25. Grass was killed and flattened to the east where runoff basically doesn't occur, and sand to the northeast of the vent was channeled by runoff which left the north rim of the pool. No changes in overflow, pool level, or bubbling were noted in connection with eruptions by Giantess Geyser.

Conditions (except the noted overflow surge) were identical to last year's observations (Landis, pg. 10). Marler noted eruptions of the spring following the 1959 earthquake, with overflow occurring after the earthquake but not before (Marler, pg. 271).

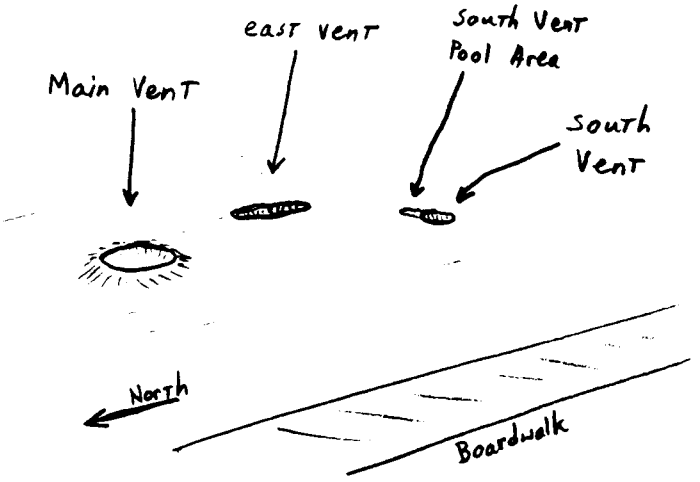
AURUM GEYSER

Prior to an eruption, audible gurgling accompanied by bursts and splashes from inches to three feet in height were expelled by the main vent. During this time the southernmost satellite vent would bubble or spit up enough water to form a six-inch pool with spits from 1 - 6 inches high. Hot cycles with intervals of about 20 - 30 minutes occurred prior to an eruption. These cycles were noted by numerous 1 - 2 foot splashes for a duration of around 10 minutes. Water from these splashes puddled the entire area west and north of the geyser. Finally one splash would remain elevated at two or more feet for at least five seconds and then a steady column of water slowly rose over 10 or more seconds to a maximum height of 15 - 20 feet. The water column arced to the west-northwest and many times wetted the boardwalk from splashing rebounding off the sinter near the boardwalk. Eruptive height decreased during the last 10 seconds to an empty vent, usually quickly followed by one or two 2-or-more foot bursts. Strong sub-surface rolling gurgling then followed for one hour before early June to about 2 hours after mid June. More on this follows. Wet splashing and gurgling would then slowly build up in intensity prior to the next eruption.

Aurum was not as consistent this year as last year. Prior to early June Aurum's average interval was 3h 21m (Fig. 2, pg. 221), which was very close to the 3h 30m average noted last year (Landis, pg. 11). Durations prior to early June averaged 60s compared to 52s last year. After early June of this year, intervals became extremely inconsistent, with ranges from 6 to over 34 hours. The average interval then became 25 hours. During these long intervals, the cyclical pre-eruptive splashing noted earlier would continue hour after hour. Eruption durations remained about the same as before mid June.

The eruptive form was altogether different from late April until early May. During this time, pre-eruptive activity by the southern vent (see drawing

this page) included overflow reaching 10 - 20 feet to the east-southeast accompanied by cyclical 6 - 24 inch eruptions. This activity was followed by weak eruptions of Aurum that reached 10 - 15 feet at most. After mid-May the strong play by the southern vent was much reduced and Aurum's eruptions regained their normal height. This was a return to activity very similar to last year. Notice that the increase in Aurum's interval length in early June occured at about the same time as the increase in eruptive durations of Little Anemone Geyser.



Aurum was observed to erupt early or late during eruptions of Giantess. Aurum's change to long inconsistent intervals prior to Giantess' first eruption may be the form of connection that exists between the two geysers. This year's durations are shorter, and eruptions a little higher than the 90 seconds and 15 feet noted by Marler (Marler, pg.. 272). Marler noted periods of dormancy in the past. The latter part of this year's activity could be leading to another period of dormancy. Eruption durations have decreased from the two minute average that followed the 1983 earthquake (Hutchinson, pg. 614).

BEACH SPRING

Periods of stronger boiling (2 - 6+ inches) accompanied by a rise in pool level from about one foot below rim top to actual surface overflow occurred. Durations of upper pool level boiling were between 45 and 90 seconds, with intervals between boils of 22 to 46 minutes. Intervals were one extreme or the other with short durations following short intervals. Overflow reached to either an inner or outer raised sinter ring, though once overflow passed beyond the outer ring (this was never observed last year). No noticeable change in activity occurred during this year's eruptions of Giantess. Activity this year was basically the same as noted last year (Landis, pg. 14). Marler noted seasonal periods of overflow, and occasional 2 - 3 foot bursts and ebbing related to eruptions by Giantess (Marler, pg. 273). The spring's appearance has changed very little since it was first named in the late 1880's for the raised sinter rings resembling beaches (Whittlesey, pg. 21).

BEEHIVE GEYSER

Two distinct modes of pre-eruptive activity presented themselves this year (Page 222). Prior to mid-May, Beehive's intervals varied between one and three days. At this same time the second (close to cone or c-c) indicator accompanied the main indicator prior to Beehive's eruptions. Activity by the c-c indicator also coincided with activity by four satellite vents near the main cone. Then about mid-May, there was a shift to one day intervals and away from activity by any of the satellite vents or the c-c indicator. Note that this shift occurs about the same time as Aurum's return to normal eruptive form, and occurs about one month before Little Anemone's shift to longer durations. Something happened on Geyser Hill during late May and early June. Now back to Beehive.

Over the course of the summer the main indicator played fairly consistently for an average of 12m 30s prior to Beehive's eruptions (Fig. 2, pg. 223). Play by the main indicator included a sudden appearance of water, quickly followed by bubbling. Within 10 seconds of the first visible water, the indicator was bubbling/bursting at least 6 - 10 inches. The height of this play reached from typically 2 - 4 feet (the height of the main cone) to 10 - 15 feet on occasion. Play by the indicator was fairly steady prior to Beehive's eruptions. Beehive eventually gave more and more 4 - 8 foot full, wet bursts followed by a slowly building water column over 10 - 20 seconds to a height of around 100 feet. About 1/3 the way through an average 5m 20s eruption (Fig. 1, pg. 223) the steam phase would begin with eruptive heights then reaching 150 - 200 feet. Eruptive height decreased during the last 30 - 45 seconds to wisps of steam; after which the cone dried off and was absolutely quiet (no steam, nothing) for several hours.

Beehive was twice observed to erupt with no indicator. John Muller observed the first time, and John and I (among others) observed the second time. Prior to the eruption, spitting and boiling was not outstanding and the indicator was empty. Suddenly Beehive gave two or three 4 - 8 foot bursts and "took off" as normal, building right into an eruption. The main indicator played weakly (1 - 3 feet) about one minute into the eruptions and lasted about another minute. Beehive's eruption appeared normal in every respect.

Eruptions tended to occur between 1000 and 1600 hours (Fig. 2, pg. 224) with an average eruption time of 1400 hours. Eruptions would occur later and later each day (an interval a little over 24 hours) and finally jump back to "morning" eruptions to repeat the cycle. Excellent work by many thermal observers and Park Service naturalists assisted in proving this pattern out. There were occasional night-time eruptions. When these occurred, no eruptions were observed the following day; followed by an "early" morning eruption the day after that. Beehive's intervals averaged 40 hours this summer (Fig. 1, pg. 224). Notice the multi-modal interval pattern. I find it interesting to note that Beehive erupts "in the afternoon" and Vault Geyser always erupted in the morning or before noon (when its eruptions were independent of Giantess' eruptions).

Around the end of August, Beehive's intervals suddenly jumped away from 1 - 2 day intervals to three or more day intervals. Activity by the c-c indicator and the four satellite vents also resumed at this time. Last year these vents and the c-c indicator were active all summer, and Beehive's intervals averaged 4 days. There is an apparent connection between activity by the c-c indicator and four vents, and longer intervals.

In summary, Beehive's intervals shortened up about 2 months prior to Giantess' first eruption, after which they lengthened slightly. Then following Giantess' second eruption, Beehive's intervals jumped to much longer time spans. Beehive erupted simultaneously with Giantess during one of its liquid-phase eruptions which follow the steam phase. I hope someone was at "lower Hams" to take a photo -- it would have been unique, and the light was good.

Here's a quick summary of activity by the c-c indicator and the four satellite vents. See the map on page 331 for the locations of these vents. Details are similar to that described in last year's report (Landis, pg. 15).

The c-c indicator was observed to play 20 - 30 minutes before (and once 11 minutes after) the main indicator began to play. Eruptive heights were from 1 - 3 feet. Eruptions had the same form as the main indicator, but weaker and more bubbly. Both indicators quit at the same time (about 3 minutes into Beehive's eruption). This activity is the same as last year. During this summer when the c-c was not active, lightly forced steam would be expelled from the c-c after an eruption by Beehive.

The south pool (last year's Valentine Pool) had visible water (in overflow toward Plume) days before an eruption by Beehive. Some bubbling was observed (though rarely). The pool's level would rise to rim top (a change of 1/2 - 1 inch) the morning of Beehive's eruptions. The pool's level would drop from view by the end of Beehive's eruption. This activity is the same as last year.

The west vent bubbled just visibly this year and sometimes not at all. The vent was empty following Beehive's eruptions. There was much less activity this year than last year.

The west pool never had visible water in it this year. Last year this pool drained and filled in accordance with Beehive's eruptions.

The far west vent bubbled minutely or up to 1 - 2 inches in height days before an eruption. Waves of overflow could be seen in response to the bubbling. Bubbling increased in height to 4 - 6 inches the day of Beehive's eruption and proved the best predictor as to what day Beehive would erupt. After Beehive's eruptions there was steam and a lot of gurgling though occasionally the pool was empty and quiet after an eruption. This activity was the same as last year; though this year the bubbling stopped by the end of Beehive's eruption whereas last year the bubbling continued for another 10 - 20 minutes.

This summer's period of one day intervals is similar to intervals observed during the 1870's and 80's (Marler, pg. 174, Whittlesey, pg. 22). This summer's change in interval length from long to short to long is typical of Beehive's trend of inconsistency over the greater part of Park history. This year's period of 1 - 2 day intervals was not quite as predictable as the 15 hour average intervals which followed the 1983 earthquake (Hutchinson, pg. 614).

BIG CUB GEYSER

No eruptions of Big Cub were observed this year. Last year's solo eruption (Landis, pg. 20) was the first since 1952 (Marler, pg. 284). This year, the geyser's pool remained 6 - 8 inches below rim top with slight bubbling. The pool was always clear. No apparent changes occurred around eruptions of Lion Geyser. Big Cub produced occasional 6 - 12 inch bursts this year, as it did last year.

BRONZE AND SILVER SPRINGS

Bronze Spring was in overflow with a clear, calm pool during most observations in April and May. During this time Silver Spring boiled and splashed from a clear pool whose level was from inches below overflow to out-of-view (from the boardwalk). By late May Bronze had ceased to overflow, and remained this way most of the time until early September, when Jens Day observed Bronze in eruption.

Prior to an eruption, Bronze's pool was about 8 - 10 inches below overflow, with slight bubbling and a murky pool. The pool level would slowly rise over several minutes time, accompanied by an increasingly apparent pulsing pool level. Bubbling would trend toward boiling when the pool level was 2 - 3 inches below rim top, just prior to an eruption. At this time thumps were once felt deep underground after which the bubbling decreased for another minute of so. Otherwise the bubbling/boiling would suddenly be disrupted by a 6 - 12 inch splash about one foot in diameter. A pause followed (along with a rise in pool level), then more and bigger individual bursts occurred (usually 2 - 5 feet) with a maximum burst height of 12 - 15 feet. Occasional full-vent domed bursts complete with an audible "pop" occurred. These bursts mimicked Deep Blue Geyser's bubble bursts in form and sound. Note that both geysers erupted from non-overflowing pools. Bronze's eruptions continued with individual bursts of varying size until a long pause (5 - 10 seconds) occurred which signaled the end of the eruption. Eruption durations averaged 70s and intervals averaged 9m 29s (Fig. 1 & 2, pg. 225). following an eruption, the pool level dropped from near rim top to 8 - 10 inches below overflow in about one minute's time. The pool then remained calm for about another four minutes, after which bubbling and pulsing developed again.

Bronze's eruptions had a series form which in September lasted several hours and 4 to 8 days between series. By early November series were lasting 2 - 3 days, and occurred roughly four days apart. Numerous coins and small rocks were thrown from Bronze by its eruptions.

Silver Spring's activity didn't seem to be affected by individual eruptions of Bronze Spring. Silver did appear connected in that its pool sometimes remained inches below or actually did overflow during the two months of eruptive activity by Bronze.

Bronze's overflow early this summer and eruptive activity later in the summer somewhat coincided with Little Anemone's shift to longer eruption durations. This is compared to last summer when Bronze had no overflow all summer and Little Anemone was true to its name (Landis, pg. 8 and 22). No connection between Bronze and Little Squirt was noted during Bronze's eruptions. Bronze's eruptions this summer may relate to Giantess' eruptive activity.

The present condition (this year and last) of no algae around either pool shows a definite increase in water temperature from the algae-lined pools present throughout Marler's observations (Marler, pg. 286). The 1959 earthquake stimulated the boiling which at present continues in Silver Springs. 1964 was the last date Marler noted pool temperatures hot enough to kill the algae growth. From 1965 - 1970 both pools were again line with algae. Bronze produced trickle overflow following the 1983 earthquake (Hutchinson, pg. 614).

CASCADE GEYSER

Cascade's pool remained clear and in constant overflow throughout the summer. A multi-colored algae bed extended from near the geyser to the Firehole River. No bubbling was observed in the pool. Large blocks of sinter wall have collapsed into the geyser to form a pile of rubble at the bottom; somewhat like Sapphire Pool in Biscuit Basin. These conditions this are the same as last year.

The last observed (and probable) eruptions occurred during four weeks after the 1959 earthquake (Marler, Pg. 287), and for one week following the 1983 earthquake (Hutchinson, pg. 614). Prior to these occasions, eruptions were observed around the turn of the century.

CHINAMAN SPRING

The spring's clear pool was constantly boiling (2 - 4 inches high) and was not observed to overflow. TW employees soaped the spring in late summer, but no eruptions occurred. I think this spring is soaped by employees ever year. The spring was said to erupt on numerous occasions in the late 1800's (Whittlesey, pg. 35). Were these eruptions soap-induced, or did the soaping destroy the geyser? Both are probably true.

COPPER KETTLE SPRING

The pool was always clear enough to read the dates on the latest pennies that were thrown in. I noted much more overflow activity from the spring this year than last year. (Landis, pg. 24). I never observed any bubbling either year. Periods of a non-overflowing pool occurred again this year, with the pool level varying from 1 - 4 inches below overflow. This year's increased days-of-overflow could imply a connection with Giantess, since it was active this year and not last year. Maybe all visitors should have to pass through metal detectors before entering the geyser basins.

DEPRESSION GEYSER

Various amounts of overflow occurred prior to an eruption. The pool was always clear with no bubbling between eruptions. Overflow was primarily to the southwest with the pool level 2 - 4 inches below the rest of the rim (during overflow). A rise in pool level to rim top accompanied by slight overflow to the north-northeast implied either an eruptive false start or a pending eruption. The former might result in a few large bubbles rising from the southernmost of the geyser's two vents; followed by a drop of 6 - 10 inches in pool level. No overflow would then occur and an hour's wait could be counted on until the next eruptive try. I never observed more than one good try at an eruption without an eruption occurring on the next try. Pool overflow to the north-northeast was then followed by the pool overflowing its entire rim, which created quite a cloud of steam. The steam cloud was very helpful in noting from a distance when an eruption was soon to begin. Individual large bubbles from both of the geyser's two main vents produced continued bursts, otherwise bursts were from the southern vent only. Most bursts were 1 - 4 feet high, with occasional 6 - 8 footers. One last burst would mark the end of the eruption for an average duration of 3m and average interval of 4h 25m (Fig. 1 & 2, pg. 226). The pool level would then drop 2 - 3 feet, followed immediately by 4 - 8 inch bursting from a small vent on the west-northwest edge of the bottom of the main crater. This vent played up to 5 minutes during which the main pool level continued to drop to a lowest point about 3+ feet below ground level. Usually this small spouter would then quit, though occasionally stop and restart to bubble at a lesser rate for 2 - 4 more minutes. The pool would take about one hour to refill to the point of overflow. Overflow then varied prior to the next eruption.

Eruption durations this year (3m) were very close to the 3m 10s average last year (Landis, pg. 25). This year's interval of 4h 25m was notably longer than the 3h 45m average last year. The form of eruptions and false starts

were the same both years. Depression showed no effects due to eruptions by Giantess, just its steady, yet fluctuating interval pattern.

Depression was stimulated into its present eruptive pattern by the 1959 earthquake (Marler, pg. 288). Prior to this time constant overflow was the norm with occasional rare eruptions. Interval lengths increased from 2 - 3 hours after the 1959 earthquake to about six hours prior to the 1983 earthquake. The 1983 earthquake shortened intervals back to 2 - 3 hours (Hutchinson, pg. 614). This year's 4h 25m average may imply the geyser is slowing down again and needs another earthquake to rejuvenate itself.

DOME GEYSER

Dome remained in steady overflow between series of eruptions. Initial eruptions were preceded by a surge of overflow from the geyser. Subsequent eruptions occurred from a non-overflowing pool. Each eruption was a series of individual domed bursts at ground level or to about 4 - 6 feet above ground. Since most eruptions occurred from a pool 2 -3 feet below ground level, many bursts reached to ground level only. Eruptions ended as quickly as they started, much like Vault Geyser. The final eruption was followed one interval later by a slow rise in pool level to about 3 feet down, followed by much boiling, then calm and a 4 - 6 inch drop in pool level. Eruption durations and intervals within a series averaged 5m 30s and 19m respectively (Fig. 1 & 2, pg. 227). Eruption series lasted from one to four days, and intervals between series averages 19 1/2 days. Three out of seven series of Dome eruptions occurred on the same day as eruptions by Vault Geyser (page 264). Dome never erupted during an eruption by Giantess, and generally erupted 10 - 20 days before Giantess erupted, and didn't erupt until at least 10 days after Giantess erupted.

Dome's eruption durations this year were very close to the 5m 38s average last year, and intervals were shorter than the 25m average last year (Landis, pg 27). Jet-like eruptions occurred following the 1959 earthquake with activity before and after the earthquake infrequent (Marler, pg. 289). The last two years' activity is a large increase since the infrequent activity noted by Marler. An exchange of function between Dome and Vault was common following the 1983 earthquake (Hutchinson, pg. 614). As noted above, at present half of Dome's eruptions occur without Vault, and half with Vault. A tendency away from an exchange of function may be occurring. The present eruption form, domed bursts, is much like that noted in 1927 by Phillips via Marler.

DOUBLET POOL

The pools remained clear and in constant overflow this summer. Doublet Pool continued to exhibit periods of pool surface pulsing and audible, heard, and felt thumping. The two pools were calm for about 20 minutes following a period of thumping. The pool level was about three inches below rim top at this time. Slight but noticeable ripples then traveled across the pools for another 10 minutes though primarily across the eastern pool where the source of the activity was located. Finally bubbling would begin in the eastern pool, followed by a rise in both pool's levels to near rim top and the thumping would begin. Stronger thumps occurred during the first half of the duration of thumping, with the time between individual thumps increasing as the thumping cycle came to a close. The last thump would be quickly followed by a drop in pool level back to about 3 inches below rim top. The average duration and interval of thumping was 9m 36s and 36m respectively (Fig. 1 & 2, pg. 228). This compares with last year's durations and intervals of 8m 15s and 34m 15s (Landis, pg. 29); thus there has been little change in Doublet's activity over the past two years.

During eruptions of Giantess, Doublet's pools would have their periods of thumping, but at a pool level about 3 inches lower than normal. This occurred early on during all three of Giantess' eruptions this year. Doublet has been known to erupt during eruptions of Giantess (Marler, pg. 290). The present constant overflow is the same as noted in all past observations.

EAR SPRING

The spring's clear pool bubbled or boiled (1 - 3 inches high) all summer. Overflow was constant to the south. Bubbling and boiling always occurred at the southwest rim of the pool and occasionally in the center of the pool. The pool level never seemed to fluctuate; though the boiling was noticeably stronger (up to 6 inches high) during one initial eruption of Giantess. No surges of overflow (to the west) occurred all summer, though old evidence of this activity remains. Surges of stronger overflow were noted after the 1959 earthquake (Marler, pg. 292) and after the 1983 earthquake (Hutchinson, pg. 614).

GIANTESS GEYSER

Giantess erupted three times this summer, which was the longest series of eruptions since 1985 (Page 229). Intervals between this year's eruptions were (in order) 51 days and 21 days. Eruptions were preceded by occasional 3 -4 foot boils many days before the eruptions, as well as the same size boils the day of the eruptions. These boils were similar to those I observed last year, with no eruption last year. I observed all of this year's eruptions about 10 - 20 minutes in. Allan Friedman was at Lion Geyser for the start of one of Giantess' eruptions and provided the following information on this summer's second eruption:

1417	Three foot boil for over one minute, then climbs in height to about 30 feet.
1418.30	Pool overflows entire rim.
1418-1420	Thumps felt on hill.
1435	When I arrived on the hill at this time there were individual and overlapping 20 - 30 foot bursts.

The first eruption this summer was by far the strongest of the three eruptions. This eruption was a mixed one with a liquid eruption, and a steam phase followed by a series of liquid eruptions. Here is what happened:

0858-0925	Initial liquid eruption (100 feet at most)
0925-0937	Rolling steam (pause in forced output)
0937-0944	Second eruption (50-70 feet, 100 feet at times)
0944-1113	Steam phase (considered stronger than usual)
1113-1137	Steam pulses
1137-1244	Individual liquid bursts (40 - 50 feet)
1244	Individual eruptions begin, lasting 28 hours.

Graphs of Giantess' eruptions and activity on Geyser Hill for the summer's three eruptions are on Pages 230, 231, and 232. The summer's second eruption was like the first except there was only one initial eruption, followed by a steam phase and mixed activity which led up to a series of individual eruptions. The third eruption this summer was a liquid-only one. A transition (mixed activity) period occurred between the initial eruption and the series of individual eruptions, but no steam phase occurred. Total eruption durations for the three eruptions were 32 hours, 31+ hours and 25+ hours. Duration of initial eruptions preceding eruption series varied between 7 and 31 minutes (Fig. 2, pg. 233). Steam phase durations were 42 and 89 minutes.

Eruption durations within the post transition-phase eruption series averaged 8m 25s with intervals averaging 33m (page 233). These eruptions were preceded by individual bursts from rim height to at least 80 feet, though usually 20-40 feet. These burst became closer together as an eruption neared. Finally a quick series of bursts would signify the start of an eruption. The eruption continued with individual yet overlapping bursts, the tallest of which were near the end of the eruption. One average burst was measured at 167 feet by Heinrich Koenig. A 200 foot marker is located by first standing at Sponge Geyser and then taking 9 steps (27 feet) toward Giantess. A 170 foot marker is at the corner of the boardwalk by Infant Geyser. The eruptions ended many times with a very tall burst, after which calm ensued for one to ten minutes (depending on the interval) before individual bursts began which led up to the next eruption. The geyser's 42-foot deep surface bowl partially filled with water between these eruptions. Toward the end of the series of eruptions the bowl filled enough that the entire pool was sometimes thrown into the air, forming a huge domed bubble which burst and returned to the crater rim with a loud resounding crash. Following the end of all eruptive activity, the geyser required a little over 3 days to refill to the point of overflow. Vault's eruptions continued after Giantess ceased erupting, but both geysers refilled to overflow at about the same time.

The geyser's main vent enters the 42 foot deep bowl from the east-southeast and appears large enough to stoop and walk down. Marler notes that an extremely strong eruption in 1963 cracked the sinter on the vent's east side

(above the main underground vent) thus changing the direction of overflow from west to east. (Marler, pg. 300). The constant overflow between eruptions is presently still to the east, though signs of the old westward overflow are apparent upon close inspection.

Other thermal features definitely affected by Giantess' eruptions include:

Beehive Geyser	Lion Geyser	Sulphide Spring
Doublet Pool	Plate Geyser	Teakettle Spring
Ear Spring	Plume Geyser	Vault Geyser
Infant Geyser	Sponge Geyser	

Changes in normal behavior prior to Giantess' initial eruption were also noted in:

Anemone Geyser Group	Inverted Geyser
Arrowhead Spring	North Goggle Geyser
Aurum Geyser	Unnamed spouters between Plume and Plate
Bronze Spring	
Copper Kettle Spring	

The figures on pages 234 - 236 compare Giantess' activity to that of Old Faithful. The four figures on page 237 show that Giantess' series of eruptions do not act as Old Faithful does, where a long duration is followed by a long interval. The other figures do note that Old Faithful was experiencing a series of long-short interval oscillations each time that Giantess began erupting. I looked into this further for the July 8 and 9 Giantess eruption and compared Giantess, Old Faithful, Beehive and Lion Geyser for the period of July 6 - 9, 1988. Notice that what I observed last year occurred again this year, namely that Lion tended to erupt around the time Old Faithful erupted, and it did so on every occurrence during the four-day period. Also note that Beehive erupts about the time Old Faithful erupts, prior to Giantess' eruption on July 8th. The possibility of connections between Beehive and Old Faithful have been noted before. The relationship I observed this summer is readily apparent on July 8 where at about 0800 Giantess begins erupting and Old Faithful enters a period of long-short interval oscillations. I then looked for this trend in all three of this summer's Giantess eruptions, as well as last winter's Giantess eruption on

December 11, 1987. The results appear in Figures 1 - 3, page 254. Here I note that in Figure 2 Giantess erupts near the start of periods of Old Faithful interval oscillations; that is within 10% of the overall average interval between periods of Old Faithful long-short interval oscillations. I therefore conclude that there exists a connection between these two large geysers, and the connect is distant (i.e., deep underground, possibly at a main source feeding this end of the Upper Geyser Basin). More on this subject is presented in the section on Old Faithful, page 59.

The following is a list of Giantess' eruptions since mid-1985.

Eruption date	Interval
7-9-85	39d
6-12-86	333d
7-15-86	33d
2-17-87	217d
3-14-87	25d
4-4-87	20d
12-12-87	254d
7-8-88	209d
8-28-88	51d
9-18-88	22d

Giantess was very active between 1870 and 1930 with eruptive heights up to 250 feet (Whittlesey, pg. 62). There was less activity between 1930 and 1980 (Marler, pg. 293) but since then the geyser has been fairly active with a record 41 eruptions occurring in 1983.

GOGGLES SPRING

The spring produced periodic overflow throughout the summer. This overflow was in concert with overflow from North Goggle Geyser. The spring's western pool was always clear, occasionally bubbled, and was the source of all overflow. The spring's eastern pool is lined with a bed of brown algae and served only as an outlet for runoff from the western pool. No eruptions were observed this year, though one burst from the western pool wetted the boardwalk last year (Landis, pg. 44).

It was mentioned to me that early photos show Goggle Spring as having two springs, and that they were connected by an arced channel. The arced channel exists today and it is by this channel that water flows from the west spring to the east spring. I probed the east spring's present algae bed to see if it is filled in with rocks, etc. below the algae. I measured probe depths from 1/4 to 10 inches, with the deepest area being the southeast quadrant. I think Marler is correct in stating the "the other seems to be clogged with tourist-induced rubble (Marler, pg. 302). I think this spring should be cleaned out and returned to its former beauty.

HEART SPRING

The spring was in constant overflow this summer. The pool was clear and occasional individual rising bubbles were observed. Small fluctuations in pool level had amplitudes of about 1/8 inch, and corresponding slight changes in the amount of overflow occurred. The fact that the pool retains its beautiful clear blue color implies that the multitude of coins thrown in are not yet clogging the spring's primary source. No connections were observed between this spring and eruptions by Giantess Geyser.

The spring's activity remains consistent with last year's observations (Landis, pg. 33). The spring's opening has been occasionally lined with algae, and was so during 1969 (Marler, pg. 303). No algae has lined the pool walls this year or last. Overflow has been observed during all present and past observations. Intermittent individual bubbles are still expelled, as was observed following the 1983 earthquake (Hutchinson, pg. 615).

INFANT GEYSER

The geyser's pool level remained about two feet below rim top during non-active periods of the summer. This location is at the top of a prominent sinter shelf extending along the western side of the geyser's vent. At these times the pool was calm and greenish-clear.

Infant proved to be the most notable indicator of pending eruptions by Giantess Geyser. Infant began producing individual bubbles 10 - 18 days before Giantess erupted on July 8 and August 28. Infant barely had a chance to return to its normal pool level following the August 28 eruption before Giantess erupted again on September 18, thus no bubbling occurred in Infant prior to this eruption of Giantess.

During the other two occurrences of bubbling, this activity fluctuated considerably from day to day with weak bubbling (individual bubbles) occurring along the west, north, and east edges of the pool. Intermediate bubbling reached 1 - 2 inches in height and occurred in the before-mentioned areas as well as the central pool. On some days stronger bubbling was an honest boil from 2 - 4 inches high and could be heard from a distance of 10 feet. No major pool level fluctuations occurred during any of this activity. Fluctuations that did occur amounted to 1 or 2 inches at most. The pool did not become cloudy due to the bubbling.

Infant's pool would begin to rise from its normal location (at the shelf about 2 feet below rim top) about 1 1/2 hours into gGantess' eruptions. Slight pool surface pulsing was noted at this time and bubbling gradually increased. The pool level rose 3 - 4 inches above its initial level in about 2 1/2 hours. At this time the pool was murky in appearance, and actual eruptions could be timed. These eruptions amounted to periods of stronger boiling from 6 - 10 inches in height, primarily from the central pool. Eruption durations

averaged 21s and intervals averaged 1m 40s (Fig. 1 & 3, pg. 238). The pool level continued to rise over the next 20 hours or so to a point about 1 1/2 feet below rim top, this point being even with the top of the gravel shelf tucked underneath the southern end of the geyser's oval crater opening. Many visitor-induced sticks collect at this point. There are also several rocks on this gravel shelf. Infant's eruptions continued throughout and after Giantess' eruptive cycle (32+ hours). Cyclical but small boiling (2 - 4 inches) was observed 16 hours after Giantess quit erupting, with a pool level nearly returned to the pre-eruptive height. The pool was still cloudy at this time. Infant would exhibit only occasional bubbles 38 hours after the last eruption of Giantess. At this time the pool level would be rising slowly, and clearing up a little. Within about 40 - 55 hours after the last Giantess eruption Infant's pool would have risen to within 6 - 8 inches of overflowing its rim top. The pool was then calm and slightly murky. This extreme pool level persisted for about 6 days, after which the level slowly began to drop. The pool level returned to normal 14, 16, and 20 days (in order) following the three eruptions of Giantess. The pool was clear again at this time.

Prior to the 1959 earthquake, Infant was normally in overflow and eruption of Giantess produced 1 - 3 foot eruptions in Infant (Marler, pg. 304). Between 1960 and 1963 Infant erupted several times each day independent of Giantess. Infant's only eruptions since 1963 have been in connection with Giantess. Sometime in the mid-1970's Infant quit overflowing on a regular basis. The pool level was about 2 - 3 feet below overflow (its typical present level) following the 1983 earthquake (Hutchinson, pg. 615).

INVERTED GEYSER

Inverted has not recovered (and probably never will) from blowing itself apart as a result of the 1983 earthquake (Hutchinson, pg. 615). The pool presently remains clear and about 1 1/2 - 2 feet below overflow. Periods of pool surface pulsing and an occasional 6 - 12 inch splash are all that remain to the geyser's activity. Thermal observers tell me that past eruptions included a steam phase followed by a liquid phase, hence the name Inverted Geyser. Present durations of pool surface disruption average 5s with intervals averaging 16m 30s (Fig. 1 & 2, pg. 239). I did not observe any overflow this summer, and there were many days in the early summer where no activity occurred whatsoever. Last year, overflow occurred on occasion along with durations and intervals of activity (splashing and pulsing) averaging 35s and 10m 35s respectively (Landis, pg. 35). Thus activity noticeably decreased this year.

LION GEYSER

Lion Geyser continued to have series of eruptions this year. Prior to the first eruption of the series, pre-play splashes would reach 1 - 3 feet above the cone. This play commenced at least 1 - 2 hours before the initial eruption of a series. Finally a burst would sustain itself for 4 - 6 seconds to a height of 3 - 4 feet and then slowly climbed in height to a 30 - 40 foot liquid eruption. The liquid eruption changed to a steam/liquid mix 1 - 2 minutes into the eruption, along with an increase in height to 60 - 90 feet. 98 feet was measured during one eruption. A pause in the steam phase lasting 10 - 15 seconds occurred about one minute before the end of many eruptions, after which the steam output resumed with no loss in strength. Steam output slowly reduced to a rolling steam cloud with no forced output. I noted this time as the end of an eruption.

I once observed a roar preceding the first eruption of a series. Roars usually only accompanied the second and subsequent eruptions of a series. Lion received its name in 1877 for its steamy roars (Whittlesey, pg. 89). Initial eruptions of a series lasted 6 - 13 minutes (Fig. 3, pg. 240), and subsequent eruptions lasted 3 - 5 minutes. One series I observed consisted of five eruptions, one of which was a minor. Minor eruptions reached heights of 20 - 30 feet and these liquid-phase-only eruptions lasted 15 - 45 seconds. The overall average duration (minors and majors) was 5m 29s, and average interval was 78m within a series. Intervals between series (start to start) varied from 7 - 10 hours.

During the Giantess eruption on July 8, I observed Lion to have a one eruption series. This eruption lasted an unusually long 12m 50s. A 10h 05m interval followed this eruption. This was the only time this year or last that I observed a one eruption series. In all other cases there were at least two eruptions per series. Since Giantess was active during this rare one eruption series, I assume there is a connection between these features. Last

year's average durations and intervals were 6m 06s and 80m respectively (Landis, pg. 36). Both of these averages were longer than this year's though the form of eruption was the same. Lion has undergone 10 - 20 hour intervals and periods of dormancy in the past, though play before, during, and after eruptions sounds much the same as today (Marler, pg. 305). Lion was dormant for 15 months following the 1983 earthquake (Hutchinson, pg. 615).

LIONESS GEYSER

Lioness was not observed to erupt this year. This fits the pattern of the past that when Lion is active, Lioness and Big Cub are not (Marler, pg. 307). Lioness' pool remained near rim top with occasional 6 - 12 inch splashes from north to south and vice versa. Lioness has not erupted since 1952 (Marler, pg. 307). At that time there was a trend away from Lioness/Big Cub eruption duels to Lioness-only eruptions (Marler, pg. 284).

LITTLE CUB GEYSER

Little Cub continued since last year to be the most active member of the Lion Geyser Group with numerous minor and major eruptions occurring. Minor eruptions consisted of light spits (reaching about 1 foot at most) where each drop of water could be seen. Duration of minors averaged 1m 25s (Fig. 1, pg. 142). Major eruptions consisted of a steady spray reaching 3 - 6 feet in height. These eruptions climbed to full height in about 30 seconds, and lasted an average 12m 15s with play tapering off during the last several minutes of the eruption. Intervals between majors averaged 1h 22 m. Last year's average duration (15m) and interval (98m) were longer than this year (Landis, pg. 40). This year's decrease in activity could imply a shift toward dormancy of Little Cub (and probably Lion) and a rejuvenation of Lioness and Big Cub, since in the past it was noted that Little Cub was dormant when Lioness and Big Cub were active (Marler, pg. 309). Little Cub does not emit steam when the other three members of the group are quietly steaming. Major and minor eruptions were noted in the 1950's (Marler, pg. 309).

LITTLE SQUIRT GEYSER

Eruptions were a steady spray from 2 - 6 feet in height. During eruptions a pool of runoff formed to the east of the geyser's vent. Eruptions lasted several hours, and observed intervals varied from 1 - 15 days. The geyser was not as active this year as last year. No eruptions were seen during most of June, July, and August of this year. This corresponds approximately to the time when Little Anenome was most active. Little Squirt did not appear connected to Bronze Spring. The former's visible water level fluctuated with no apparent pattern relating to the latter's eruptions. Little Squirt's activity is currently much less than the steady eruptions following the 1959 earthquake (Marler, pg. 310). Prior to the earthquake, eruptions occurred on an irregular basis. Little Squirt erupted almost daily following the 1983 earthquake (Hutchinson, pg. 615).

MODEL GEYSER

Random 1 - 4 foot eruptions were observed this year and last year (Landis, pg. 43). Eruptions were constant overlapping bursts which were clearly audible from Sponge Geyser. Eruptions grew slowly in height, remained at maximum height for usually several minutes, and then lost height (faster than they grew in height). No connection was observed with eruptions of Giantess Geyser.

MOTTLED POOL

I observed one burst from the pool which reached ground level. Otherwise boiling confined itself to an occasional one-foot splash from a clear pool whose level was about five feet below ground level. Constant bubbling separated the occasional splashes. Vegetation still grows down the walls of the vent, as noted in 1927 (Whittlesey, pg. 103).

NORTH GOGGLE GEYSER

The geyser was much less active this year, compared to last year. One major eruption and a handful of minor eruptions were observed this year. I observed one minor eruption this year, lasting seconds at a height of 3 - 4 feet and occurring two 77m intervals after the last eruption of a Lion eruption series. This two interval waiting period fit the pattern noted last year (Landis, pg. 44). The singular eruption I observed occurred during a Giantess eruption series. I did not observe any apparent direct connection between the two, though North Goggle is connected to Lion which is connected to Giantess.

North Goggle exhibited periodic overflow in unison with Goggle Spring. Durations of the former's overflow averaged 1m 49s and intervals averaged 11m 6s (Fig. 1 & 2, pg. 242). The pool was always clear and occasionally (though rarely) bubbled. The first definite eruptions of North Goggle occurred after the 1959 Earthquake (Marler, pg. 311). The geyser has been active most every year since then except for dormancy in 1962 and 1963.

OLD FAITHFUL GEYSER

Pre-play bursts occurred 5 - 10 minutes prior to an eruption, though sometimes no pre-play was observed. Some of the bursts were 10 to at least 20 feet in height. Most eruptions began with a sustained outpour for 5 - 10 seconds to a height of at least three feet, after which the water column rose steadily. Maximum heights were around 120 - 150 feet. Durations and intervals averaged approximately 3 - 5 minutes and 77 minutes respectively. No true steam phase occurred, and the strength of the eruption gradually decreased during the last minute. No activity existed between the end of one eruption and the pre-play which preceded the next. Predicting the "following" interval based on the "just finished" eruption duration proved fairly reliable, with results being within + or - 10 minutes about 90% of the time. The equation used to predict eruptions had to be changed following this year's August 24 eruption, to longer intervals.

I performed a lengthy study on Old Faithful's eruption interval pattern. Periods of long-short intervals occur, where a "long" interval is followed by a "short" interval, and then another "long" interval, etc. I noticed a tendency for Old Faithful to enter into a period of long-short cycles at about the time Giantess began erupting. Do the long-short interval cycles express a connection between the two geysers? I chose as a definition of a long-short cycle the following:

1. A 20 minute interval fluctuation followed by a second 20 minute interval fluctuation.

   -or-

   A 10 minute interval followed by a 20 minute interval.

2. At least two complete long-short interval oscillations (i.e. long-short-long - one cycle).

3. The two complete long-short cycles must be completed in at most 5 intervals.

4. At least two non-oscillating (stable) intervals are required to separate two periods of long-short interval cycles.

The definitions were chosen as a means to break up Old Faithful's overall interval pattern, according to the short-term interval patterns which seemed most apparent. Researchers could simply compare oscillating to non-oscillating intervals and arrive at much the same conclusion as I did.

Graphs of Old Faithful's daily interval pattern leading up to the December '87 and July '88 eruptions of Giantess can be seen on pages 243 - 252. Pages 248 and 252 each contain a graph of when the long-short cycles occurred vs. day of the month, as well as a graph of when the longer intervals between long-short cycles occurred vs. day of the month. No consistent trends exist in the activity graphed on these pages, which implies that no long-term trends occur in Old Faithful's long-short intervals prior to eruptions of Giantess Geyser. Page 253 contains graphs of Old Faithful intervals for + or - 2 days around the last four Giantess eruptions. Note here that Old Faithful enters a period of long-short interval oscillations at about the time Giantess erupts. Results of this tendency are graphed on page 254.. These results show that on the average, Giantess erupts within 3 hours (10.3%) of the start of the average interval (29 hours) between periods of Old Faithful interval oscillations (Figure 1). Also note that the durations of Old Faithful's periods of interval oscillations increase by 25% after Giantess erupts (Figure 2), and that the interval between these periods of interval oscillations increases by 18.5% after Giantess erupts.

If Old Faithful's long-short interval cycles are thought of as "hot periods" in the geyser's activity, then the geyser enters a hot period close to the time that Giantess erupts. After Giantess' eruption, the hot periods become longer and further apart, which matches Old Faithful's pattern of long durations relating to long intervals. The point is that Old Faithful exhibits a large-percentage shift in its trend of activity following an eruption of Giantess. This changing trend can be thought of as a change in the second derivative of Old Faithful's intervals. That Giantess erupts near the start of

one of Old Faithful's hot periods in 4 out of 4 cases implies that a definite current connection exists between the two geysers.

The lack of a long term trend on Old Faithful's intervals prior to Giantess' eruptions implies that the heat buildup in Giantess is independent of Old Faithful. It is possible that a heat surge from the two geysers' source sends Old Faithful into one of its periods of long-short intervals and at the same time promotes an eruption in Giantess (when all of this geyser's other time-related requirements are correct).

PENDANT GEYSER

No eruptions were observed this year or last (Landis, pg. 46). Constant overflow from a clear pool occurred both years. This year the pool surface pulsed slightly during most observations. Last year no pulsing was noted. Occasional bubbles were seen this year. Pendant last erupted following the 1983 earthquake with almost continuous spouting to under 2 meters observed, followed by near dormancy in 1984 (Hutchinson, pg. 615).

PLATE GEYSER

Prior to Giantess' first eruption on July 8, Plate's eruptions were separated by no overflow or pre-play bursting. Plate would fill to overflow seconds before erupting. Bursts climbed to one foot high in seconds, with full eruptive height (4 - 8 feet) reached within 10 or 15 seconds. Eruptions then continued at full height for the majority of the duration. Heights dropped off during the last minute to about 2 - 3 feet, and then tapered off to nothing over about 5 seconds' time. Occasionally (though rarely) there would be one last 4 - 8 inch spit immediately following the eruption. Eruption durations and intervals averaged 5m and 2h 12m respectively (Figure 1 & 2, page 255; though intervals of 4 and 5 hours were observed by reliable sources. Last year's durations and intervals averaged 5m and 2h respectively (Landis, pg. 47).

During the July 8 eruption of Giantess, Plate was bubbling and in light overflow four hours into Giantess' eruption. This was the first time this year or last I had seen overflow without an eruption. Water would be "up in the vent" about 20 minutes after an eruption, along with trickle overflow hours before pending eruptions. Eruption intervals gradually shortened from four hours at the start of Giantess' eruptions to 5 minutes about 19 hours into the eruption (Page 230). These 5m intervals continued on and off for about 5 hours, with durations of 30 - 90 seconds. During the summer's eruptions of Giantess, Plate's durations and intervals averaged 1m 48s and 64m respectively (Fig. 3 & 4, pg. 255). A comparison of these durations and intervals shows a slight trend of short durations followed by short intervals (Fig. 1, pg. 256).

Water was visible in Plate's vent (or overflow between eruptions occurred) during most of the observations during the rest of the summer, thus there has been a definite shift in the non-eruptive activity between last year and the latter half of this year (Landis, pg. 47). I assume Plate's overflow will

cease long before Giantess' next eruption. The geyser's average interval remains less than the 3 - 4 hour average which was common following the 1983 earthquake (Hutchinson, pg. 615). Eruptions were evidently rare prior to the 1983 earthquake.

PLUME GEYSER

Plume's pool level remained 8 - 12 inches below overflow between all of this year's eruptions. The geyser's two pools filled to overflow about 5 seconds before an eruption, after which the first burst quickly followed. Burst heights varied from 1 - 25 feet, with 15 - 25 feet common. The number of bursts per eruption varied from 3 - 5; though 4 bursts was by far the most common (Fig. 3, pg 257). Each burst lasted 8 - 12 seconds and intervals between bursts increased slightly as the number of bursts progressed (Fig. 1 - 4, pg. 258). The pool level was out of view between bursts. The average eruption duration and interval was 60s and 27m respectively (Fig. 1, pages 257 & 259). Water was visible in the vent about 15 - 20 minutes after an eruption.

The geyser's original vent played much stronger this year than last, with this vent's play either equal to or higher than the "new" vent which formed during the winter of 1972-73.

Plume was definitely affected by Giantess Geyser. Plume's intervals lengthened 5 - 15 minutes above the average during the start of or the first 3 - 5 hours of Giantess' eruptions (Fig. 1, pages 230, 231, 232.). Plume's intervals returned to "normal" about 5 hours into Giantess' eruptions in all cases. During these longer intervals a single burst eruption was once observed, as well as a four burst eruption with each burst about two feet high and of normal duration. Eruption durations and intervals during activity by Giantess averaged 60s and 28m respectively (Fig. 2, pg. 257 & 259). Overall there was only a short term apparent effect on Plume by Giantess.

Plume's average interval this year was much shorter than the 30 - 90 minutes noted last year. This may be because last year Plume overflowed between most of its eruptions (Landis, pg. 49). Plume did not show the

diurnal trend this year that was observed last year. I believe I was correct in stating (last year) that increased activity by Giantess (as occurred this year) might overshadow Plume's diurnal pattern noted in 1987. This year's eruptions from a non-overflowing pool is a return to the same trend which followed the 1983 earthquake (Hutchinson, pg. 616).

Plume's vent evidently blew out in 1922 (Marler, pg. 312). The geyser was dormant from 1924 to 1941, after which it rejuvenated and has been active with varying consistency ever since.

"POT O' GOLD" SPRING

One eruption was observed from the north vent on July 28. David and Michael Goldberg observed the eruption and provided the following information:

Duration: 4 minutes
Height: 2 feet

The vent 3 yards south-southwest (Pot O' Gold proper) drained 4 - 8 inches during the eruption. This vent stayed empty during the entire eruption; after which both vents slowly refilled.

Fine grey sinter/sand (and the previously existing brown and red algae) was blown from the north vent during the eruption. The pool in this vent was slightly murky the day following the eruption, and occasional bubbles were seen at times during most of the rest of the summer. The red and brown algae mat in Pot O' Gold collapsed as this pool drained during the eruption of the north vent. The day following the north vent's eruption, Pot O' Gold's pool was calm and clear. Some seepage overflow occurred from both vents for a few weeks following the eruption.

By mid-November both pools were about one inch below overflow and algae was re-growing in both vents, most notably in Pot O' Gold. No eruptions from either vent occurred last year.

PUMP GEYSER

Water flow from this constant spouter was continuous all summer. The runoff continues to support a beautiful algae bed west of the geyser. The algae bed's living "area" located five yards downstream from the geyser shifts in a river-delta growth pattern. The geyser's constant splashing reached from 1 - 6 feet in height, with 1 - 3 feet most common. The taller (3 - 6 feet) play came and went in an irregular yet cyclical pattern. Last year's 7 foot and higher bursts were not seen this year.

Pump has been erupting steadily to 2 - 3 feet since before 1927 (Marler, page 314). The 1959 earthquake had little or no effect on the geyser. The 1983 earthquake decreased the geyser's output enough that the large algae beds died at that time (Hutchinson, pg. 616).

ROCK POOL

The pool's level remained about 2 - 3 feet below rim top during all observations. The pool retained a milky-grey color. On rare occasions an individual bubble was observed. No algae grows in the pool or in the pool's vent. All of these conditions were identical to observations in 1987.

Rock Pool has suffered repeated vandalism since the late 1940's by being filled to ground level with pieces of ryolite. (Marler, page 315). Park Service or concessionaire employees are usually to blame for this type of "yearly" vandalism.

SCISSOR SPRING

The spring's western vent exhibited various degrees of overflow during all observations. This pool was clear and no bubbling was observed. Runoff from this pool filled both "cutting edges" of the original scissor. The spring's eastern vent remained clear and bubbled or mildly boiled at all times. This pool's level fluctuated about on inch, the upper levels of which reached about 1/2 inch below overflow. These observations were identical to those noted last year (Landis, pg. 55). Steady converging flow from both springs has not occurred since 1950, except for a short rejuvenation following the 1959 earthquake (Marler, pg. 317). The spring's western pool ceased to overflow following the 1983 earthquake (Hutchinson, pg. 616).

SOLITARY GEYSER

A calm, clear pool was present between eruptions. Trickle overflow to the southwest and northwest occurred at this time. Extensive yellow to brown algae beds were supported by this overflow. The pool level would begin to rise about one minute prior to an eruption. Occasional bubbles and pulsing of the pool surface occurred at this time. Stronger overflow occurred about 10 seconds before an eruption, followed by wavelets of overflow. Eruptions consisted of individual bursts from 1/2 to 3 feet high. One to four bursts occurred during an eruption. Pauses lasting over 30 seconds separated some of the bursts; though these pauses usually were only 3 - 10 seconds long. The pool level dropped immediately after an eruption, but not enough to stop all overflow. The runoff in certain areas seemed to stop for at most one minute just after an eruption. Eruption durations and intervals averaged 16s and 5m 12s (Fig. 1 & 2, pg 260). Last year durations and intervals averaged 39s and 5m 37s respectively (Landis, pg. 56).

SPONGE GEYSER

The geyser's pool was about 6 - 8 inches below rim top between eruptions. Bubbling was constant at this time. The bubbling increased in strength as the pool level began to rise about 15 seconds before an eruption. Stronger bubbling occurred as the pool level first began to rise. During this time some spits of water reached about 10 inches above the pool level. These spits reached out of the vent and wetted the down slope of the cone's outer runoff area. An eruption began with the pool level remaining at its highest level (about 3 - 5 inches below overflow) accompanied by 3 - 5 inch bubbling to the top of the rim. The eruption ended as the pool level began to drop; though some strong spitting occurred at this time also.

The quietest periods occurred at the lowest and highest pool levels. My eruption durations and intervals are actually these periods of "high" pool level, and averaged 8s and 89s respectively (Fig. 1 & 2, pg. 261). Last year's durations and intervals averaged 13s and 92s respectively (Landis, pg. 57).

Sponge's pool level dropped 1 - 2 feet below rim top during all three eruptions of Giantess. This drop occurred sometime between 8 and 18 hours after the start of Giantess' eruptions. By 24 hours into Giantess, Sponge's level was about 2 feet below rim top. Sponge's eruptions continued normally at these low pool levels. The pool level gradually returned to normal 11 - 13 days after the end of Giantess' eruption.

Sponge's pool level dropped over 8 feet as a result of the 1959 earthquake, and took about one year to recover (Marler, pg. 318). Activity before and since then has remained basically the same. A rise in the geyser's pool level occurred following the 1983 earthquake (Hutchinson, pg. 616).

SULPHIDE SPRING

The spring overflowed only occasionally this year. During the first half of the summer the pool level was generally 2 - 3 inches below overflow. Constant bubbling from 1 - 4 inches high occurred at this time in the spring's southern pool. This pool was generally semi-clear with occasional murkiness due to some algae growth. The spring's northern pool contained brown algae growth along with occasional bubbles. Following many days of no overflow, Sulphide's southern pool was observed in steady flow one hour into an eruption of Giantess.

The spring's southern pool was soaped once. This produced 6 - 10 inch constant spitting. No overflow was occurring prior to or during the soap induced eruptions, thus it was several days before the effects of the soap wore off. Visitors threw an exceptional number of sticks into the spring this year.

This year's long periods of no overflow were a change from the constant flow that was observed last year (Landis, pg. 54). The spring first overflowed following the 1959 earthquake, and apparently this year's state of no overflow is new for this spring (Marler, pg. 319).

TEAKETTLE SPRING

Long periods of a hissing steam sound (much like that heard in a sea shell) occurred with a pool level at least 4 feet down (barely visible at all). Shorter periods of constant bubbling were occasionally heard. The pool was always clear. There were no observable changes in activity at the start of any of Giantess' eruptions. Three days following the end of the last eruption of Giantess, Teakettle's pool level was 1 1/2 feet below rim top with a constant boil. Four days after the eruption, Teakettle was still boiling about 2 - 3 feet below rim top. The spring was back to normal (quietly steaming/hissing) 11 days after Giantess' eruption ended. Note that Infant's pool level also rises and falls after Giantess' eruptions end.

Teakettle's pool level was at rim top prior to Vault's rejuvenation in 1947. Since then the spring's level has steadily dropped (Marler, pg. 321). Water was visible in the spring (with bubbling) until October of last year; after which the level dropped to its present position, and the hissing sound ensued. (Landis, pg. 60).

TOPAZ SPRING

Water remained visible about 8 or 10 feet down in the spring's vent. Plants continue to grow several feet into the vent. These observations are consistent with last year's findings (Landis, pg. 61). No changes in activity were noted during this year's eruptions of Giantess. An early reference states that water flowed from the spring in 1927 (Marler, pg. 322). Marler's observations found the spring empty except for four years following the 1959 earthquake.

VAULT GEYSER

Vault's pool was clear and in constant overflow to the northeast between all series of eruptions. Overflow east of the geyser was stronger than usual at least one hour prior to an eruption series. At this same time, the pool level periodically rose enough to submerge a small sinter island at the north end of the pool. The two just-mentioned conditions served as reliable indicators that an initial eruption was very near. Initial eruptions begin with a surge of overflow followed by a steadily increasing boiling eruption form. The boils reach from 3 - 4 feet on up to over 20 feet during the initial eruption. Periods of stronger boiling came and went at this time. One initial eruption duration of 20m 50s was noted. This was common with last year's observations (Landis, pg. 62). Strength of the eruption generally tapered off during the last 1 or 2 minutes. Boiling at this time was from a pool level down into the main surface bowl of the geyser. Large amounts of water pour from the geyser during all eruptions. A calm pool about 5 - 7 feet below rim top was present between eruptions. Subsequent eruptions began from a partially refilled vent (4 - 6 feet below rim top).

These subsequent eruptions began instantly with boiling startling people nearby. The eruptions reached ground level about one minute into the eruption, after which bursts reached from ground level to 10 feet in height, sometimes a little more. These eruptions tapered off near the end with ground level or lower boiling. The eruptions ended as quickly as they began. A gurgle/draining sound immediately followed the end of activity. Eruption durations and intervals averaged 4m 28s and 53m respectively (Fig. 1 & 2, pg. 262). Eruption series always began in the morning (before 10 a.m.) unless accompanying an eruption of Giantess. I once observed 13 eruptions in a series, including the initial. The series of eruptions began much like last year with a definite pattern to the intervals (Fig. 1, pg 263). The average interval between series was 11 days (Fig. 3, pg 262 and Fig. 1, pg. 264). Note

that Vault's last series prior to eruptions of Giantess occurred 2 - 22 days beforehand.

Eruptions of Giantess caused Vault's pool to drop. This drop began immediately upon Giantess' starting to erupt. The pool level continued to drop to a level about 5 - 6 feet down, being calm the entire time (about 3 hours). Bubbling would then begin, subsequently turning to a boil about 3 - 4 hours into Giantess' eruption. The point would come when the pool level rose the 5 - 6 feet to rim top in about two minutes, accompanied by very strong thumps easily felt at Infant Geyser. The pool level then remained inches from overflow with waves (2 - 3 inches high) passing back and forth along the length of the pool, as well as 3 -5 inch pool level pulsing. This lasted about one minute, after which the pool overflowed its entire rim for 30 seconds and the eruption began. These initial Giantess-related eruptions had durations over 30 minutes, fully half again as long as other initial eruptions (Fig. 5, pg. 262). All subsequent eruptions barely reached ground level, and otherwise had the same basic eruptive form as described above. Average durations and intervals of Vault's eruptions while Giantess was active were 4m 8s and 60m respectively. The intervals increased in length as Giantess' eruption progressed (Fig. 1, pg. 230). Vault continued to erupt at least 20 hours after Giantess' eruptions ended. Vault and Giantess' pools refilled at about the same time (3 days) following the end of Giantess' eruptions.

Vault's durations and intervals last year averaged 4m 20s and 55m respectively, and intervals between eruption series averaged 4.25 days (Landis, pg. 62). This year's longer intervals were such that yellow and orange algae grew within 1 - 6 feet of the geyser's vent, only to be washed away by the next series of eruptions. Vault was dormant at least 20 years prior to 1947 (Marler, pg. 323). Following the rejuvenation, Vault has experienced various amounts of activity, with this year being much less active than last year. As in the past, less activity by Vault generally means more activity by Giantess. The 1983 earthquake had little effect on Vault's eruptive activity (Hutchinson, pg. 617).

"FROG POOLS"

These two pools are east of Liberty Pool, and lie along the north side of the Boardwalk. Both pools have thick growths of green mat-like and spine-like algae. The algae coverings extend from the pools' edges out across the pools' surfaces to about 1/2 the pools' radius. The pools' centers are greenish clear to a depth of one or two feet. Frogs were observed in the eastern pool this summer and in the western pool last summer.

LIBERTY POOL

A thick bed of green algae grows in this pool. Green algae grows on the pool surface, but not in a thick mat. The pool is green with algae though the bottom of the pool (about 2 feet down) can be seen. The pool is in constant overflow from a western runoff. No bubbles were observed. Liberty was seen erupting 50 - 75 feet high on July 4, 1887 (Whittlesey, pg. 87).

"PULSING POOL"

This pool is east of Liberty and Frog pools, and lies on the south side of the boardwalk. The pool is clear and exhibits periodic overflow. Overflow occurred when the pool level rose 1 - 2 inches, and was accompanied at this time by a pulsing pool surface. Durations of this pulsing overflow varied between 5 and 50 seconds with an average of 31 seconds. Intervals of the activity varied between 51 and 110 seconds with an average of 68 seconds. The pool level dropped below overflow between periods of pulsing, and the pool was then calm. No bubbles or breaking of the pool's surface occurred.

CASTLE GEYSER

Pre-play bursts occurred at random intervals prior to Castle's eruptions. These bursts reached a few feet out of the cone 1 - 4 hours prior to an eruption. If these bursts are considered as "hot periods," then hot periods begin about halfway through an interval. I believe a pattern to these hot periods exists as to their increasing frequency prior to an eruption;. Though some eruptions are immediately preceded by substantial pre-play every few minutes, while others have no pre-play for roughly 20 - 40 minutes beforehand. The height of the pre-play bursts generally increases from the "few feet" (2 - 10 feet) mentioned above to 20 - 30 feet (or more) as an eruption nears. Most of these bursts last 2 - 5 seconds; though on occasion some last 5 - 10 seconds. These bursts don't shoot from the cone, but they don't rise gently from the cone as eruptions tend to do.

An eruption's initial water column rises almost gracefully from the cone to a height of 20 - 60 feet above ground level. The water column's height usually fluctuates and at times actually stops completely for 2 - 4 seconds. These pauses generally occur during the first few minutes of an eruption. Once the eruption is underway, overlapping bursts are the norm and some of these reach 60 - 90 feet in height. One eruption this summer began by bursting from the cone with some force; rather than the usual graceful play. The eruption's initial liquid phase lasts about 18 - 25 minutes, when a strong steam phase slowly replaces the liquid phase. The steam phase exhibits periods of stronger output which can be heard from Geyser Hill, Daisy, and occasionally from the Grotto/Giant area. Steam phases lasted 1 - 2 hours for a total eruption duration of about two hours. Steam output decreased slowly enough that it was difficult to define a true end to the eruption. Steam eventually rolled from the cone and finally stopped, after which there was a quiet period of no activity prior to the initiation of pre-play bursts.

Intervals between major eruptions observed by naturalists, observers, and myself averaged 10h 51m for the summer (Fig. 1, pages 265 & 266). Page 266 shows the occurrence of minor eruptions and the interval between the minor and the following major. No apparent long-term trend exists between major eruption intervals and the occurrence of minors. Minors began like majors, but then suddenly stopped. Much bursting (more than prior to an eruption) occurred between a minor and the next major. Some of these bursts lasted over 10 seconds and reached heights of over 50 feet. I never observed 2 minors back to back. Minor eruption durations averaged 5m and the average time from a minor to the next major was 6h 23m (Figures 2 & 3, pg. 267). Figure 1 on this same page compares the duration of minor eruptions to the delay between that minor and the next major. No consistent trend occurred this year, though last year a rough approximation of the delay (in hours) was calculated by taking the duration of the minor (in minutes) and then converting minutes to hours (Landis, pg. 71). This year, if no minor eruption occurred, Castle's interval was very consistent at "10h 40m plus or minus 30 minutes."

The small pools and spouters at the northern base of Castle did not provide a consistent indicator as to when Castle would next erupt. the pools filled and drained at random, one or several hours prior to an eruption. Play by the small spouters did not begin with a consistent pattern prior to an eruption, nor did the strength of their play provide any indication. The cyclical (though constant) play by Tortoise Shell Spring did not appear connected with Castle, though the two features' close proximity would imply some sort of relationship. Last year I observed one possible affect on Castle's eruption by Grand Geyser (Landis, pg. 71). This year I only observed possible affects on Grand Geyser by Castle Geyser. I also wonder if the delay between Castle's minors and majors is more consistent (as it was last year) when Giantess Geyser is not active (as occurred last year), though Rick Hutchinson informed me that the make-up of Geyser Hill's water is different from that of Castle's water. Castle's water is the same as Grand's water. Note that the dead trees west of Castle are about the same age as the dead trees east of Grand. All these trees were killed by increases in activity, though Castle's may have died from shifting runoff channels more so than renewed activity.

Castle played infrequently in the 1920's and 30's, but has been fairly active since the 1940's and has changed very little since 1960 (Marler, pg. 214). Marler first noted in 1946 what I today consider a minor eruption.

CRESTED POOL

The clear pool was in constant overflow. Superheated bubbling was almost always present and occasional 1 - 6 foot boils lasted about 4 - 10 seconds. The boils were considered as eruptions by some observers. No significant increase in overflow was associated with these boils.

The pool level dropped (to one of no overflow) as a result of the 1959 earthquake (Marler, pg. 222). At this time a definite relationship with Castle Geyser was noted. Two periods of eruptive activity were noted by Marler in the past (1952 and 1968). The heights of the 1952 eruptions were the same as what I've observed on many occasions this year and last. The duration of the 1968 eruption was at least twice as long as the longest I've seen.

SPRINKLER GEYSER

One possible 65 minute interval was noted separating periods of constant play from 1 - 5 feet high. The geyser was active all summer in that eruptions were observed on several occasions during any given day.

Past observations note eruptions occurred several times a day, though the regularity of this activity was undetermined (Marler, pg. 253). The geyser has been active since the late 1880's when it was named by the Hague expedition.

TILT GEYSER

One eruption of Tilt was observed this year on May 2, from Geyser Hill. The eruptive height was about 4 - 6 feet, and eight minutes later a strong steam phase was noted. Runoff from Crested Pool drowned Tilt for the rest of the season. Occasional pulsing and bubbling would appear through the runoff covering the southern vent. At other times Tilt's southern vent drew in Crested Pool's runoff like a vacuum. Crested Pool's runoff grows in a river-delta growth pattern by depositing in one area and gradually shifting to another location. By early November, the runoff was shifting to the south and away from Tilt. Many eruptions of Tilt were observed last year. The geyser's original vent is connected to a newer vent blown out about 2 feet north of the original vent. I seem to remember being told by John Railey that liquid eruptions exit from one vent and steam phases occur from the other.

BELGIAN POOL

No overflow occurred from the clear pool, and no bubbles were observed. The pool level did not fluctuate, remaining several inches below overflow. No connections with any of the Sawmill or Grand groups were noted. Jens Day and I removed the large flat rocks that had been thrown into the pool and used to line the old asphalt footpath. We also removed a large rock that was lodged across the main vent and which "had been there as long as remembered" according to several observers.

The pool's present level and lack of activity remain consistent with all past observations (Marler, pg. 211).

The pool was named for a Belgian who fell into it and later died, in 1929 (Whittlesey, pg. 23).

BULGER GEYSER

Bubbling preceded eruptions by about three minutes, with no water visible at this time. Eruptions included a visible pool of water and continuous bursting to heights of 1 - 5 feet. The pool emptied immediately after the eruptions. Eruption durations and intervals averaged 5m 10s and 49m respectively (Fig. 1 & 2, pg 268). Occasional individual light 1/2 foot bursting lasting less than one minute occurred during the otherwise quiet period between eruptions. Periods of audible bubbling sometimes occurred at this time, though no water was visible.

The geyser's intervals prior to 1959 and from 1960 - 1972 were between 3 1/2 and 4 1/2 hours (Marler, pg. 212). Evidently activity is picking up, though the current eruption heights are less than the 6 - 8 feet noted by Marler.

CHURN SPRING

I never observed an eruption by Churn Spring. The pool level fluctuated from 1 - 2 feet below rim top to trickle overflow. Bubbling was usually occurring, and was related to all pool levels about one foot below overflow or higher. Periodic overflow has been noted only since the 1959 earthquake (Marler, pg. 220).

The name commonly used at present is Churn Geyser because eruptions have been observed on occasion, evidently after 1972 when Marler published his observations.

"CRYSTAL SPRING"

The spring displayed periods of pulsing overflow. The pool level remained 1 - 2 inches below overflow between periods of overflow. Some bubbling in the always clear pool occurs between overflows. Occasional six inch bursts occurred during periods of overflow. Durations and intervals of overflow averaged 44s and 2m 25s respectively (Fig. 1 & 2, pg 269). No changes in activity were noted as activity progressed in the Sawmill Group.

The small geyser whose 1 - 2 inch diameter vent is about one foot down Crystal Spring's southern runoff channel was not observed to erupt (by me), though other observers have seen eruptions from this feature.

OLD TARDY GEYSER

A wide variation in eruption durations and interval lengths was observed. Light spitting was observed between the shorter intervals, with the pool level out of view at this time. A quiet, empty vent existed between longer intervals. Eruptions began rapidly. The overlapping bursts reached heights of 1 - 4 feet and runoff flowed into Oval Spring during the longer eruptions. Eruptions ended as quickly as they began. Eruption durations and intervals averaged 4m 20s and 19m respectively (Fig. 1 & 2, pg 270). I am sure that connections with other nearby features give Old Tardy its wide variation in intervals and durations. The geyser's irregular activity has been the norm in all past observations. (Marler, pg. 241).

OVAL SPRING

Overflow was never observed from the spring's clear pool. Fluctuations in pool level were from inches below overflow to about four feet down. The entrance of a large cavity south of the spring is visible at lower pool levels. I observed one 2 - 3 foot burst lasting 5 seconds. This burst occurred at a nearly overflowing pool level. Other eruptions of this form were observed this year. Connections with other members of the Sawmill Group is certain, due to the fluctuating pool level. Past observations note the non-overflowing spring remained about 4 inches below overflow during most observations (Marler, pg. 243).

PENTA GEYSER

Penta's five vents were generally empty of water and quiet. Water was visible in the vents prior to eruptions of Sawmill Geyser. At this time Penta's vents slowly filled with an oscillating pool level. The separate pools that developed over two of the three small vents next to the main vent would finally connect at upper pool levels. What the observer hoped for was that this combined pool would fill higher yet and flow to the south. This time was most promising for an eruption. Several eruptions were observed this summer. I observed one "in eruption" that lasted another 46 minutes at a height of 15 - 20 feet from the main vent and a 3 - 6 feet from the three closest satellite vents. The eruption lost height and ended in about five seconds, after which the water quickly drained in the vents. Strong thrashing and gurgling began seven minutes after the eruption ended. Two eruption intervals of approximately 2d 18h and 3 days were noted with the aid of markers (Fig. 4, pg 271). Eruptions of Sawmill Geyser usually drained the rising pool level in Penta. An obvious connection exists between the two geysers. Water levels in the small vents between Penta and Spasmodic seemed to be affected by both features, though some were affected more by Penta and others more by Spasmodic. Penta's irregular eruption intervals have characterized this geyser since early observations during the 1920's (Marler, pg. 244).

SAWMILL GEYSER

The geyser's pool level fluctuated between eruptions, from out of view to overflowing. Overflow did not necessarily lead up to an eruption, though a pool level about 1 -2 feet below overflow (or overflow) was present just prior to an eruption. Eruptive heights were generally 1 - 8 feet with occasional periods of 15 - 25 foot activity which was easily heard at Grand Geyser. Play consisted of overlapping shots of water. The stronger play was a real crowd-pleaser as each shot burst from the vent. Wind-blown spray usually soaked everyone nearby. Following an eruption, the water level drained from view in under one minute. Durations and intervals averaged 40m and 2h 55m respectively (Fig. 1 & 2, pg 271). Sawmill is connected with Penta, postponing the latter's eruptions on many occasions. I think Sawmill is affected by a 22 hour or greater cycle that most of the geysers in the vicinity of Sawmill go through. 24 hour per day observations for about one week should prove or disprove this hypothesis.

Except for periods of dormancy during the 1960's, Sawmill has erupted with about the same interval (2 - 3 hours) since 1895 (Marler, pg. 246). Sawmill appeared to be as active last year as this year, though I made no specific observations last year. The current activity may represent a trend away from the periods of dormancy noted by Marler in the 1960's. Sawmill's eruptive form is basically the same since it was named for its noisy, bursting eruptions in 1871 (Whittlesey, pg. 135).

SCALLOPED SPRINGS

Scalloped Spring's pool level remained about three feet below rim top at all times. A constant splashing/boiling was present. South Scalloped Spring remained in overflow from a calm, clear pool during all observations. A bison calf fell in the south spring in February or March. The strong odor of cooked buffalo still remained when I arrived late in April. Bubbling was occurring in April when I arrived, but by mid-summer the pool was basically calm and remained so through October.

Soaping of Scalloped Spring in 1955 destroyed the spring by stopping the previous constant overflow (Marler, pg. 248). The spring's level has basically not changed since that time. South Scalloped Spring has been in constant overflow during all my observations over the last two years. This is a change from 1963 - 1972 during which Marler noted that overflow had ceased. Overflow or a rim top pool level was present prior to 1963.

SPASMODIC GEYSER

The pool levels in the geyser's two vents fluctuated between eruptions from out of view to overflowing. The pool levels were out of view only every 22 hours or more, otherwise the level dropped to 2 -4 feet below overflow between eruptions. There appeared to be a progression in the height of the pool between eruptions with each additional eruption followed by a higher "low pool" level.

Eruptions were preceded 5 - 10 minutes by occasional 1 -3 foot play from the small vent east of and between the two large pools. Steady play from this vent was noted at the start of Spasmodic's eruptions. At about this time the south pool's level would be about one foot below rim top and experiencing mild bursting to one or two feet. The North pool's level would be about 1/2 - 1 foot down and play from this pool usually followed play from the south pool by one or two minutes. The north pool began its play with occasional 1 -3 foot bursts. Several small vents around the southwest circumference of the north pool were occasionally erupting to 2 - 5 feet about 20 - 30 minutes into the main eruption. At 30 minutes into an eruption, the north pool would be spilling into the south pool, with occasional 3 -4 foot bursts. At this time the south pool would be experiencing constant 1/2 - 2 foot boils. The east vent at this time would give occasional bursts up to eight feet high. The longer duration eruptions produced runoff from the south pool toward Twilight Geyser. The north vent's activity decreased 10 - 15 minutes before the end of an eruption; boiling in the south pool lost intensity also. Activity by the east vent would finally become intermittent 1 - 3 foot bursts. I noted this time as the end of an eruption. Within 2 -4 minutes of this overall decrease in activity, the level of the two pools would begin to drop, with the south pool lower than the north pool. Light boiling continued in the south pool. The north pool would be calm, and the east vent quiet. The two pools' levels continued to drop to 2 - 4 feet below overflow, and activity in the south pool eventually

decreased to none or light bubbling. Eruption durations and intervals averaged 61m and 2h 20m to over 3 hours (incomplete interval) respectively (Fig. 1 & 2, pg 272).

I chose to start Spasmodic's cycle and that of the entire Sawmill Group at the time when the pool levels of Spasmodic, Oval, Penta, Twilight, Sawmill, Uncertain, Bulger, Tardy and Old Tardy were all out of view at the same time. This only occurred every 22 hours or more. I would not be surprised if the interval on these occurrences was occasionally over 30 hours, and there is a possibility intervals of 10 - 11 hours occurred. I believe many features in the vicinity of Spasmodic are related together, due to the large fluctuations in durations and intervals of the areas thermal features. A 24-hour a day study for about one week would prove or disprove this hypothesis. Features possibly related together include Spasmodic, Oval, Old Tardy, Penta, Twilight, Tardy, Sawmill, Uncertain, Bulger, and Churn.

Spasmodic has been active since before 1927 and has been noted to be connected to Penta (Marler, pg, 251).

TARDY GEYSER

No water is visible in Tardy's vent between eruptions. A full pool with light, sometimes overlapping 1 - 6 foot bursts characterizes an eruption. Many of the bursts are separated by half-second pauses. Eruption durations averaged at least 21m, though one eruption lasted only 2m 50s (Fig. 3, pg. 269). One eruption interval of six hours was noted.

During the 1940's and 50's, durations and intervals averaged 25 - 30 minutes and 2 - 3 hours respectively (Marler, pg. 254). Stronger eruptions were noted when nearby Sawmill was playing, thus a connection between Tardy and Sawmill existed at that time. In 1963 Tardy erupted 95% of the time. In the past, the name Tardy Geyser had been applied to (present day) Turban and Old Tardy Geysers (Whittlesey, pg. 153).

"TWILIGHT" GEYSER

At times the geyser's two pools were empty. Prior to an eruption the water level rose into view over at least one hour's time. The one eruption I observed occurred at a pool level about six inches below overflow. The eruption began with visible bubbling and light spits in both pools. Occasional strong 1 - 2 foot boils were occurring 30 minutes into the eruption, with constant bubbling between the boils. Occasional (though rare) one foot domed bursts were seen in the west pool about an hour into the eruption. Stronger activity decreased to bubbling 20 minutes before the end of the eruption. At this time the pool level was one inch below overflow. The end of the eruption was when bubbling ceased, and was followed by a pulsing pool and cyclical overflow. The eruption's duration was 2h 30m. Overflow (without the aid of the still present pulsing) was constant three hours after the eruption ended. Sawmill, Spasmodic, and Old Tardy erupted during Twilight's eruption. Marler makes no mention of an unnamed spring or geyser in the vicinity of Twilight. The name Twilight Geyser is suggested by Scott Bryan.

UNCERTAIN GEYSER

I observed one eruption of Uncertain Geyser. 30 minutes prior to the eruption, the water level was about six inches below the top of the geyser's 2 - 3 inch diameter vent. Constant bubbling was occurring at this time. The eruption began quickly. The constant spray reached heights of 4 - 7 feet. About 1/3 the way through the eruption the density of the spray decreased, though the height was still 4 - 6 feet. A slow change to a steam phase eruption occurred at this time. Halfway through the eruption, the output was 95% steam. I called the eruption over when the steam rolled from the vent. An eruption duration of 6m 30s occurred, with a 2 1/2 minute liquid phase. Old Tardy erupted halfway through Uncertain's eruption, at about the end of Uncertain's liquid phase. I assume uncertain is connected with other geysers in the area. Sawmill's pool was several feet below overflow during Uncertain's eruption. Marler makes no mention of this geyser. I don't know where the name came from.

According to Scott Bryan, Uncertain has also been referred to as Sawmill's satellite vent.

EAST TRIPLET GEYSER

No eruptions were observed this year. Eruptions of East Triplet are said to occur when Rift Geyser is active, though not necessarily in concert with Rift. I cleaned out East Triplet's vent this year with the help of a number of thermal observers. The vent had been carefully filled in by first placing rocks across the main vent and then back-filling several feet of rock and sand above the vent. I wonder if the "beginning of dormancy" noted in 1947 was the year the vent was filled in (Marler, pg. 224). At present, water pressure had forced a passageway around the back-fill along the north wall of the geyser's vent and a current sinter accumulation of 1/3 - 1/4 inch lined the passageway. This deposit thickness may support the year 1947 as when the vent was sealed off.

After cleaning out the geyser, warm water stood about six inches deep after an eruption of Grand Geyser. The water level began to rise in the vent about the time Grand had its first overflow (4 -5 hours) after an eruption. The water temperature increased enough at this time that it burned the skin. The pool level rose to about 3 - 4 feet below rim top just prior to Grand's eruption (about 2 feet deep). Most of this pool level rise could be attributed to Grand's cyclical run off eventually pouring into East Triplet's vent. No bubbling was ever observed. I assume activity by East Triplet will delay eruptions of Grand Geyser. I did not clean out the small vent about two feet west of East Triplet, at the top of the latter's vent. Maybe next time.

East Triplet played in concert with the other two Triplets prior to its dormancy (Marler, pg. 224). Eruptions then lasted several minutes to a height of 20 feet, angled toward Rift Geyser.

GRAND GEYSER

The first overflow under the boardwalk (116 feet west of the geyser) occurred about 3 1/2 hours prior to an eruption, or just over halfway through an eruption interval. After this time, trickle flow was always occurring, with periods of heavier overflow 4 - 8 minutes prior to most eruptions of Turban Geyser. Grand's pool level (over the main vent) rose and fell with each heavy overflow cycle. The upper pool levels associated with the periods of heavy overflow eventually submerged a reef-like group of small sinter islands about 5 yards west of Grand's main vent. This was an optimistic sign that an eruption was near. Waves radiating from Grand's vent during a period of heavy overflow (and upper pool levels) occurred about 30 seconds prior to all eruptions I observed. The amplitude of the waves increased to the point that whitecaps formed at the tops of the waves. Finally, bubbling or pulsing of the pool was quickly followed by a single burst to 10 - 20 feet which was then quickly followed by a climbing, constant water column to over 100 feet. Overlapping bursts began after about one minute. The duration of the first burst (series of overlapping bursts) averaged about 9m 25s (Fig. 1, pg 273). Strength of the first series of overlapping bursts decreased during the last several minutes of the "burst." Play occasionally virtually stopped, only to quickly recover to the typical height of 30 - 50 feet at this point in the eruption. The pause between the first and second burst averaged about 45s (Fig. 1, pg. 274). The second burst was usually higher than the first with eruption heights of 180 - 215 feet measured (Fig. 1, pg. 275). These eruption heights were always a real crowd-pleaser. The duration of the second burst averaged about 1m 10s (Fig. 2, pg. 273). The pause between the second and third burst (if there was a third burst) averaged about 50s (Fig. 2, pg. 274). The third burst was generally not as high as the second burst. Durations of the third burst averaged about 44s (Fig. 3, pg. 273). A graph of the duration of each burst vs. when it occurred during the eruption shows the parabolic shape of this pattern (Fig. 1, pg. 276). A power series equation of the form

$Y = F(x^n) + C$ would describe this curve. Grand's eruption interval averaged 8h 28m (Fig. 2, pg. 277) Grand's average daily interval for the summer is graphed on page 266).

Grand's pool would partially refill if an additional burst was going to occur. At this time the pool whose level was about 2 - 3 feet below overflow would began to boil and a subsequent burst would rise from the vent. Occasionally the pool would be visible, only to watch it drain away. About 15 minutes after an eruption, bursts would shoot from Grand's empty vent to heights of 4 - 10 feet (or more). This play lasted 10 - 15 minutes at most. The vent then remained empty about 3 hours after an eruption. At this time a calm pool was visible about two feet below overflow. Another 1 - 2 hours would pass before the first overflow occurred, which then led up to the next eruption.

Grand had one 5 1/2 hour eruption interval (Fig. 2, pg 277). This roughly matches the first hot period that Turban has at about 5 - 6 hours into Grand's interval (Fig. 1, pg. 280).

Rift Geyser did not erupt from April 26 - November 15. Thus Grand's average interval this season forms a basis by which eruption delays caused by activity in Rift or the Triplets can be judged. Last year's activity by Rift gave the result that one hour of eruption by Rift delayed Grand's eruption by one hour (Rick Hutchinson). Grand's pool occasionally had waves emanating from above the vent, after which the waves diminished and no eruption occurred for 1 - 5 Turban intervals afterwards. If this "false start" occurred, then Grand would have no heavy overflow one Turban interval after the false start. Heavy flow always occurred two Turban intervals after the false start. I observed one eruption of Grand coming from the no-heavy-overflow pool condition. Usually Grand waited 2 - 3 Turban intervals for its eruption (after a false start). I observed two false starts in a row (2 - 3 Turban intervals apart) on occasion.

I looked for a pattern relating Grand's false starts and eruptions of Castle Geyser. False starts occurred at most any hour before or after Castle's eruptions, and no consistent trend was apparent. This result only tells me that Grand's false starts do not show a connection with Castle; these two features may still be connected.

Graphs on pages 273, 274, and 278 compare activity during Grand's eruption and whether or not Turban or Grand initiated the eruption. The average values obtained in this comparison, along with the grouping of the data and the amount of data collected did not convince me that a specific trend was present. Collecting more data would help disclose the answer to my question. Grand showed definite connections with Turban, Vent, Rift, West Triplet, and East Triplet. Grand always erupted about the time of Turban's eruption. Vent only erupted during Grand's eruptions. Rift's eruptions delayed Grand's eruptions. West Triplet's pool rose prior to Grand's eruptions. East Triplet's pool level rose and heated up as Grand began to overflow. Grand showed some tendency for longer eruption intervals on windy days.

Grand's present eruption pattern of a long initial burst has been the case since 1969 (Marler, pg. 233). Prior to that time there were generally more bursts than at present, and longer durations. Several periods of dormancy have occurred with the most recent ones during 1942 and following the 1959 earthquake. Grand was appropriately named in 1871 for its eruptive strength which propelled water to 200 feet (Whittlesey, pg. 65).

RIFT GEYSER

No eruptions were observed between April 26 and November 15. Rift was active last year with the result that one hour of eruption by Rift delayed Grand Geyser's eruption by one hour (Rick Hutchinson). Rift erupted last year for several hours at a time. The fact that eruptions of Rift delay Grand Geyser's eruptions has been noted in the past (Marler, pg. 245).

TURBAN GEYSER

Every aspect of Turban Geyser's activity reflected what was happening in Grand Geyser. During the four hours prior to Grand's eruptions, Turban's pool was partially full between its eruptions. The pool level rose about the time an eruption began. These eruptions usually began with a single burst about 1 - 2 feet high, followed by a quiet pause lasting about five seconds. The eruption then began in earnest with a continuous series of overlapping bursts from 2 - 5 feet in height. Eruption durations averaged 5m 9s (Fig. 1, pg. 279). These eruptions tapered off in strength near their end, so a careful eye was needed to catch the end of an eruption. The average interval between eruption starts was 20m (Fig. 2, pg. 279). Turban's average interval decreased from 20m to 19m as Grand's eruption neared (Fig. 1, pg. 280).

Over the last few years, thermal observers have grown accustomed to watching Turban begin erupting, followed by Grand's eruption. This year the opposite was true with 65% of Grand's eruptions beginning before Turban erupted. If Grand erupted before Turban, then Turban's eruption followed generally in less than one minute. If Turban erupted before Grand, then Turban usually stopped shortly after the end of Grand's eruption, doing so 59% of the time (Fig. 1, pg. 281). If Turban did stop shortly after Grand's eruption ended, then Turban would restart and erupt constantly for about another 40 minutes. The interval encompassing Grand's eruption averaged 18m (Fig. 2, pg 281) which is shorter than any of the averages prior to Grand's eruptions. If Turban did not stop shortly after Grand's eruption ended, but rather began erupting about the time Grand erupted and then continued to erupt after Grand, its duration was between 61 and 65 minutes (Fig. 3, pg 279).

Whether or not Turban stopped erupting after Grand's eruption ended, Turban continued to constantly erupt for very close to one hour after the beginning of Grand's eruption. This fact was useful (and accurate) in

predicting when Grand's eruption began if the observer missed Grand's start or all of the eruption. After this long duration eruption ended, Turban's pool drained completely for 10 - 20 minutes. This proved a good time for thermal clean-up in the vicinity of Turban and Grand Geyser. Jens Day and I removed about 500 pounds of tourist-induced rocks from in and around Turban alone. After the before-mentioned 10 - 20 minute pause, water would begin to rise up and out of Turban's main one-foot diameter vent (along the west wall) with much boiling and thrashing. An interval of 20 - 40 minutes followed Turban's long duration eruption. Play then continued with approximate five minute durations and intervals of 18 - 25 minutes until the next eruption of Grand Geyser.

Turban's intervals showed a trend toward shortening up about halfway through Grand's interval (Fig. 2, pg. 280). These shorter intervals about four hours prior to Grand's eruption could be considered hot periods in the group's activity, and probably coincide with Grand's occasional five hour intervals (one occurred this year). Turban's eruptions usually lacked the single burst followed by a pause if Grand was going to erupt during that Turban eruption. Turban's eruptions would instead start and continue with no pause. Turban's durations were longer than average (20 - 30m) if Grand Geyser had a false start.

Following recovery from Grand's eruptions, Turban's play is very similar to that observed over many years (Marler, pg. 258). Marler notes that Turban has suffered extensive vandalism since as early as 1878.

VENT GEYSER

Vent Geyser only began erupting during eruptions of Grand Geyser. Vent's eruptions began after Turban's began, and was about 2 1/2 - 3 minutes into Grand's eruptions. Vent's eruptions began as a slowly growing column of water angled slightly to the west. Eruptive heights reached their maximum of 25 - 35 feet about two minutes into the eruption. This play then continued steadily throughout Grand's eruptive bursts and pauses, with the height of Vent's play commonly equaling Grand's lesser play. Vent's eruptions were mostly liquid. If Turban ceased erupting after Grand's eruption ended, then Vent would also stop erupting. This occurred about one minute after Grand's eruption ended. A quiet pause of about 10 minutes followed, after which Turban would restart with light spits and Vent would follow Turban (about 30 - 90 seconds later) with light spray to about three feet. Within one minute of this restart, Vent would be erupting to 10 - 15 feet with a constant eruption. Near the end of this play, Vent's eruption would enter a steam phase which eventually reduced to a rolling steam cloud. Vent's eruptions ended with Turban's, very nearly one hour after Grand's eruption began. Vent's play could be seen from great distances, thus its play could be easily observed. Vent then remained empty and quiet until the next eruption of Grand Geyser.

This year's concurrent activity between Vent and Turban is typical of past relationships between these two features (Marler, pg. 261). Vent has been known to occasionally erupt 90 - 120 minutes before Grand's eruptions; thus causing a drop in Grand's pool and finally an eruption of Grand Geyser.

WEST TRIPLET GEYSER

No eruptions were observed between April 26 and November 15. Algae growth occurred in the pool, and was just thick enough that it was hard to see the bottom of the pool. The pool level fluctuated from about 3 - 4 feet below rim top to about two feet below rim top in relationship to where Grand was in its eruptive cycle. West Triplet's higher pool levels served as one reliable indicator of the closeness of Grand's eruption. While standing on the boardwalk, if the observer could see West Triplet's pool at all (short observer) or see about one foot of the pool's surface (tall observer) then Grand was very near an eruption. The pool stayed up for a time after Grand's eruption ended, then slowly dropped to the before mentioned 3 - 4 feet below rim top. No bubbling was ever observed. Eruptions of West Triplet tended to lengthened intervals between Grand Geyser's eruptions (Marler, pg. 264).

BEAUTY POOL

Beauty Pool was in constant overflow from before April 26 through October 22. During this period of overflow the pool was clear and calm. Slight fluctuations in pool level occurred, amounting to about an inch. Runoff from Beauty headed north to the base of the hill about 100 yards southeast from South Purple Pool. The runoff is killing the trees in this area. Some of the runoff drains into South Purple Pool's satellite vent located 3 - 4 yards southeast of the main pool. Beauty's runoff turned west after reaching the base of the hill, passing about 50 yards south of South Purple Pool. A small grove of trees separated South Purple Pool from Beauty's runoff. At 1530 on October 22 runoff shifted from Beauty to Chromatic pool. This time I assume is plus or minus a small amount. Following the shift, Beauty's Pool remained calm and a few inches below overflow. This condition remained through November 15.

Shifting of overflow between Beauty and Chromatic Pools occurred on an irregular basis prior to 1960 (Marler, pg. 209). From 1960 - 1969 Beauty was not in overflow and the possibility of no further shifting presented itself. Current activity indicates the patterns which existed prior to 1960 have returned.

CHROMATIC POOL

Chromatic's pool was not in overflow from before April 26 through October 22. During this time the pool level was 3 - 5 inches below overflow. The pool was clear at times and darkened by algae growth at other times. Algae growth on the floor of the pool reached just into the "vertical" walls of the actual vent; thus algae growth generally covered the flatter portions of the pool floor between the vent and the outer rim of the pool. The pool was always calm. Occasional rises in pool level produced runoff which reached about 10 yards north-northeast of the pool, down the pool's primary runoff channel. No changes in Chromatic's pre-overflow condition indicated that the shift was about to occur. Chromatic began overflow at about 1530 on October 22. The pool remained calm after the shift. Past observations indicate that either Beauty or Chromatic is always in overflow (Marler, pg. 209).

ECONOMIC GEYSER GROUP

Economic Geyser and East Economic Geyser exhibited sympathetic pool level fluctuations much like that which occurs between Beauty and Chromatic pools. Fluctuations in Economic's pools had amplitudes of about 1/2 inch. These fluctuations were timed to observe any changes in activity when Grand Geyser erupted.

Economic's pool was calm at lower pool levels. Pulses in the pool surface preceded a 1/2 inch rise in pool level, and continued during the period of maximum water level. Maximum pool level was maintained from 30 - 90 seconds. The pool level began to drop at the same time the pulsing ended. The pool was then calm until pulsing began along with a rising pool level. Intervals between the start of upper pool levels were between 6m 30s and 7m 15s. East Economic's pool level was basically opposite that of Economics during the cycle of activity. The eruption of Grand Geyser during the collection of the above data did not have any pronounced effect; though an overall trend from short intervals to long and back to short occurred from before until after Grand's eruption. Durations of upper pool level varied from "long" before Grand's eruption to "short" after the eruption.

I then checked activity in Economic's pool between eruptions of Grand Geyser. The intervals between pool level pulses varied from 5m 50s to 6m 30s, and the amplitude of pool level fluctuations was at most 1/4 inch. Thus the intervals were shorter and the amplitudes less when Grand was not near an eruption.

The possibility of a connection between the Economic Geyser Group and Grand Geyser may exist. More data needs to be collected to properly answer this question.

Both pools were filled with heavy beds or reddish brown algae. Upper pool levels in Economic Geyser radiated one or two feet from the geyser's outer rim, while upper levels of East Economic's pool submerged the area west of this geyser all the way to Economic (at times). A long term oscillation in the flooding produced by East Economic's runoff was apparent, with roughly one or two months between periods of stronger flooding.

Economic Geyser was a real crowd-pleaser from the late 1880's until the 1920's with eruptions from 10 - 30 feet in height every few minutes (Marler, pg. 225). The geyser was named for its eruptions which drained back down the vent to re-use the water again (Whittlesey, pg. 50). One month of eruptions were observed following the 1959 earthquake.

SHOE SPRING

Several eruptions were observed on August 20 and 21. In May and June the spring's western pool was thick with green algae. The algae died in mid-summer, after which the algae mat collapsed in the center of the pool but remained attached to the pool's outer walls. The pool cleared in time and remained so until the August eruptions. No bubbling or pool level fluctuations were apparent prior to the eruptions. Evidently the spring slowly heated up and killed its algae growth before getting around to erupting. Runoff from the small spring east of the main spring flowed into the main spring during all observations prior to the August eruptions.

Bill Warnock provided the following information on August 20 eruption. At 1545 (40 minutes after Grand erupted) the "new vent" (Shoe Spring) had sustained boils to about 2 feet from a full pool. The eruption later reached 10 feet in height. The bursts angled toward the boardwalk. Most overflow went into the east pool (the spring east of Shoe Spring) which was empty, and a draining sound was clearly audible. At 1800 the main pool's level was down one foot and bubbling.

On August 21 a 2 - 4 inch boil lasting one minute occurred 13 minutes prior to a four foot eruption which lasted 1m 23s. A smaller boil occurred 90 minutes later and lasted 11 minutes. This activity occurred between 1831 and 2025. On November 15 the east pool was trickle-flowing into the main pool for the first time since the eruptions. Algae was slowly re-growing in Shoe Spring's main vent.

Lee Whittlesey says the correct name for this spring is Shoe Spring. Past references to this spring must exist. Knowledgeable observers say the spring has erupted on occasion during the last 10 years.

"TOPSOIL" SPRING

The spring's outer rim is oval-shaped and about 3 x 2 feet. This small intermittent spring remained in constant trickle overflow until I removed several large flat rocks from the bottom of the pool. This clean-up exposed the spring's source which amounts to a group of perforations at the base of the soup-bowl shaped spring. The pool then displayed random, periodic overflow separated by occasional pool levels 1 - 3 inches below overflow. No bubbling was observed before or after cleanup. Fluctuations in pool level did not appear to relate to eruptions of Grand Geyser. I suggest the name Topsoil Spring because the grey-black sediment in the pool looks just like the richest topsoil any farmer could ask for.

WAVE SPRING

Random bubbles rose to produce minute waves which radiated from the pool's center. The pool was lined with red-brown algae. Some days the waves were more pronounced than others. Overflow seeped in every direction from the spring. Current activity is the same as most past observations (Marler, pg. 263). Possible connections exist with Economic Geyser, as concurrent temperature fluctuations have occurred in the past.

BIJOU GEYSER

Bijou's activity was affected by activity in the Grotto Group, and by activity in Giant Geyser. Bijou's typical condition was one of constant play (overlapping bursts) from 1 - 4 feet in height. Periods of stronger play were from 4 - 8 feet in height. Bijou appeared to always be erupting unless close observations were made. Pauses in Bijou's eruptions were noted, many of which were definitely related to activity in Giant or Grotto Geysers. These pauses were called Bijou shutdowns. Pauses can be grouped into short, medium and long categories.

Short pauses lasted from seconds to about 2 1/2 minutes, with an average duration of about one minute. These pauses did not appear to be related to any other apparent activity, though I believe they resulted from the growth and collapse of air bubbles somewhere below Bijou. Medium length pauses lasted from about 2 1/2 - 7 minutes. These pauses were followed by noticeable rises in the level of Mastiff Geyser's west pool. The east pool may have risen also, but the west pool was quicker and easier to observe; also random above-ground splashes emanated from Mastiff's east pool. The pool level in Giant's indicator pool also rose during these medium-length Bijou shutdowns. The overall average duration of the short- and medium-length Bijou shutdowns was 1m 28s (Fig. 1, pg. 282). Long duration pauses lasted over 11 minutes and preceded all major hot periods in Giant Geyser. The average interval between all durations of Bijou's shutdowns was 18m 41s (Fig. 2, pg 282). Long intervals followed long shutdowns as a rule. Examples of Bijou's activity are on page 283. A four minute pause interval, preceded by a string of 20 minute (plus or minus) intervals, immediately preceded the Giant eruption on September 12 (Stephens, pg. 1). This activity is graphed on Fig. 2, page 284. During Giant's major hot periods Bijou resumed erupting about halfway (6 minutes) through the average duration of play of Giant's platform vents (13 minutes). Long intervals between pauses (1 - 2 hours) followed all major hot periods. Bijou's eruptions were always strongest

following a pause in its activity. Eruptive heights of 10 - 15 feet were noted at this time. Bijou remained off during the entire eruption of Giant on September 12 (Stephens, pg. 4). Light spits were observed 20 hours after the eruption began, and Bijou had fully recovered (erupting constantly) 37 hours after the eruption.

Numerous small vents between Bijou and Mastiff appeared to follow Bijou's on/off activity. The strength of Bijou's eruptions slowly decreased to none during all of Grotto Geyser's long duration (Marathon) eruptions. These eruptions of Grotto generally lasted 15 - 30 hours, with no activity from Bijou about 6 - 10 hours into Grotto's eruption. Bijou's recovery began 1 - 3 hours after the end of a Grotto Marathon eruption. Bijou thus remained "off" for about 12 -15 hours. Bijou occasionally resumed activity during the midst of one of the long-term shutdowns related to Grotto Marathon eruptions. Bijou would play for roughly 30 - 60 minutes, followed by a major hot period in Giant, after which Bijou would again play for, I believe, less than one hour and then stop all play until Grotto's Marathon eruption was over (Mary Ann Moss and Lynn Stephens).

Bijou's present activity is a trend away from the gradual decline in activity noted during the 1960's (Marler, pg. 126). The present form of on/off activity has occurred since 1950. The geyser was considered a continuous spouter from 1875 - 1950 with play from 3 - 20 feet. Bijou was originally named "Young Faithful" Geyser.

CATFISH GEYSER

Catfish was usually quiet, with occasional light spitting except for the following. This geyser had its best play during a pause in the otherwise steady play by Bijou Geyser. Catfish Geyser's eruptions appeared to initiate Bijou's eruption in that near the end of a Bijou "shutdown," Catfish would begin erupting a thin column of water in individual and overlapping bursts to heights of 5 - 20 feet. This play lasted about 30 seconds. Play by Bijou began about the time Catfish's play ended, with a slight overlap in the two geyser's activity of 5 - 10 seconds. Catfish occasionally gave 5 - 10 seconds of 2 - 4 foot spitting during a Bijou pause, after which there was no restart by Bijou and the Bijou pause continued.

On occasion, Catfish would erupt with actual intervals ranging from 3 - 6 1/2 minutes. Durations of play (individual spits) were several seconds at most. This play reached heights of 1/2 - 3 feet. Occasional wisps of steam occurred, and may have replaced some of the periods of light spitting. Catfish produced strong growling during the latter part of several of Giant's major hot periods. Catfish gave several 5 - 8 foot splashes about four minutes prior to Giant's eruption on September 12 (Stephens, pg. 2). Catfish and/or Bijou gave a loud roar/whistle about one minute before Giant erupted; this occurred during Mastiff's 30 - 50 foot eruption.

Catfish Geyser's present mode of activity has been observed since the 1959 earthquake (Marler, pg. 127). During Giant's last active period (1950 - 1955) Catfish and Mastiff preceded many of Giant's eruptions, and on occasion Catfish alone preceded the eruptions of Giant Geyser. These solo performances of Catfish produced eruptions to heights of 75 feet for 10 minutes.

GIANT GEYSER

Giant was noticeably more active this year than last year, or than the preceding 32 years. Two eruptions and dozens of major hot periods occurred between April 26 and November 15. Everyone listed in the acknowledgements helped contributed data on Giant's activity and Lynn Stephens prepared an excellent, detailed report on Giant's September 12 eruption. Major hot periods included play by 6 - 13 platform vents, and minor hot periods included play by one or two vents. See the map on page 335 for the locations of the platform vents. Names are those suggested by Mary Ann Moss unless otherwise noted.

Minor hot periods usually occurred with play by Posthole and Fry-pan; though on occasion play was by East #2 only. This minor play reached heights of about 1 - 3 inches and lasted roughly 3 - 15 minutes. Enough minor hot periods occurred that replacement of markers could not at times keep up with the occurrences. Major hot periods were noted with as much accuracy as possible. Major hot periods always began during a pause in Bijou's otherwise constant eruptions. These hot periods began 5 - 7 minutes into a Bijou "shutdown". The start of play by one of the platform vents was noted as the start of a hot period. Mastiff's west pool was always either in overflow or very near overflow just prior to the start of every major hot period. Vents at the southwest end of the platform always played early in a major hot period. These vents included at least #0, Southwest #1, Southwest #2, and Southwest #3. Posthole, Fry-pan, Northwest #1, and Northwest #2 sometimes played (individually, not necessarily together) at the start of a major hot period.

If play by the just mentioned vent(s) at the north end of the platform began during the start of a hot period, this play usually stopped during the hot period; yet always seemed to finish every hot period. Play by Northwest #1

and Northwest #2 switched during the course of the summer, with Northwest #1 playing from 1 - 3 feet early in the summer (little or no play by Northwest #2). Northwest #1 did not play at all by the end of the summer, rather Northwest #2 played to heights of 1 - 10 feet. Posthole erupted much like Model Geyser in form, to heights of about 1 - 3 feet. Posthole is the square vent that used to contain the post for Giant's sign. Fry-pan bubbled in its vent with occasional 2 - 6 inch light spitting.

As mentioned above, the play by the vents to the southwest generally started all hot periods but did not finish any of the hot periods. #0, Southwest #1 and Southwest #2 played together and with a flashlight showed #1 and #2 to be connected together. Mike Keller suggested the name "Squirrel Tails" for #0 and Southwest #1 because their eruptions rose straight in the air like a pair of squirrel tails, erupting to heights of 1/2 - 3 feet. Southwest #2 erupts at an angle to the west for a distance of up to about three feet and was hence named "Angle" by Mike. Southwest #3 filled with water to rim top or very near that point during all hot periods. This vent bubbled during and for at least 20 minutes after every hot period. The vent's water level stayed within 2 - 4 inches of rim top for a good hour after a hot period and thus served as a reliable indicator of the approximate time a hot period had occurred if it was recently missed. This vent's normal level was six or more inches below rim top. The blowout next to Southwest #5 enlarged from a tiny hole to one about four inches across over the course of the summer. Soft, flexible sinter could be felt down in this vent by a quick hand. East #2 generally was not active, but when it was, play reached about 1 - 2 inches at most in a bubbling eruption. I once observed a minor hot period in which East #2 was the only vent active, after which Giant gave numerous splashes to the top of its cone and angled to the south.

Durations of major hot periods averaged 13 minutes (Fig. 1, pg. 284). The overall average interval between major hot periods was 44 hours (Fig. 2, pg. 285). About half the major hot periods were followed by increased play in Giant, amounting to several individual full vent bursts to near the top of the cone (each burst's duration about four seconds) or angled columns of water (not full vent) to the south. Some bursts spilled water out the front of the cone. Some of this post hot period play only amounted to 2 - 3 foot splashes in Giant. A graph of hot periods vs. start of Grotto's eruptions is on page 286. This figure shows that most hot periods occurred prior to Grotto's eruptions.

Many occasions occurred when a Bijou pause lasted several minutes, only for Bijou to restart and soon be followed by an eruption of Grotto Fountain and Grotto.

My trend of thought at first was that there were specific windows of time when a hot period would occur in relation to the start of Grotto's eruptions. The more data I collected the more windows I added, and finally concluded what Figure 1 on page 286 shows: There are no specific "windows" when hot periods occur other than that 75% of all observed major hot periods occurred prior to Grotto's eruptions. Figure 2 on page 286 compares major hot period occurrences with Grotto marathon eruptions. Sixty percent of Giant's hot periods that occurred near the time of a Grotto marathon did so after the marathon eruption began, which correlates well with the fact that both of Giant's eruptions occurred during (shortly after the start of) a Grotto marathon eruption. This implies that Grotto marathon eruptions indicate an overall energy peak in the Giant/Grotto complex. Grotto's marathon eruptions possibly act as an outlet for water flow such that when enough water is "drained off" Giant's system (via Grotto) that Giant then erupts. Assuming that this is correct, I wonder if Beehive's indicator serves the same purpose. Grotto's marathon eruptions would then serve as Giant's indicator.

Giant's major hot period intervals along with Grotto's marathon eruption intervals are graphed on page 287. Note the overall trend of simultaneous long Grotto marathon intervals and short hot period intervals. The opposite is also true. Note that after the October 5 earthquake that both intervals increased in length. Bijou pauses leading up to Giant's eruption on September 12 are shown in Fig. 2, page 284.

The most notable activity which foretold Giant's September 12 eruption included:

1. Heavy overflow from Mastiff during Giant's last major hot period two days prior to the eruption.

2. Grotto's marathon intervals increased from 48 hours five days before Giant's eruption to 72 hours at the time of Giant's eruption.

3. Giant's major hot period intervals shortened from over 40 hours (7 days prior to Giant's eruption) to a string of 16 - 25 hour intervals (5 in a row) just prior to Giant's eruption.

4. A two day period of no major activity in Giant or Grotto (marathons) led up to Giant's (and Grotto's) eruptions. This thoroughly confused all the observers, including myself.

A quick summary of Lynn Stephens' observations on Giant's September 12 eruption: A major hot period immediately preceded Giant's eruption. The eruption was a Mastiff function with Mastiff erupting from 30 - 50 feet about two minutes prior to the eruption. Giant's water column rose steadily once its eruption began, and was estimated at at least 200 feet high four minutes into the eruption. The platform vents were all off 20 minutes into the eruption, and Mastiff was no longer erupting one minute later. Giant was in a mixed steam and liquid eruption 37 minutes into the eruption. The steam phase died out 47 minutes into the eruption. Platform vents resumed playing 51 minutes into the eruption. Giant ejected steam and liquid bursts from 53 minutes to 69 minutes into the eruption, after which the eruption ended as no more activity occurred. Grotto continued to erupt after Giant's eruption; this was also observed following the June 28 eruption. The first splashes of water from any feature in the vicinity of Giant occurred 21 hours after the eruption. Bijou and Catfish splashed lightly at this time, followed about 20 minutes later by the first splash from Giant's cone.

Prior to all major hot periods, the water in Giant's cone rose to within about three feet of the lowest point on the rim (west side of cone), or about even with the general level of the platform. Periods of stronger boiling within Giant itself were separated by actual calm at times.

The eruption on September 12, 1987 was very muddy, with a brown cloud visible from Geyser Hill. This year's September 12 eruption (two eruptions later) was composed of clear, clean water. The pool level of South Purple Pool dropped several inches below overflow following the June 28 eruption this year.

Thermal features directly or indirectly connected with Giant include:

Bijou Geyser	Marathon Pool	South Grotto Fountain
Catfish Geyser	Mastiff Geyser	Spa Geyser
"Giant Indicator Pool"	"platform vents"	Turtle Geyser
Grotto Geyser	Purple Pools	"Variable Spring"
Grotto Fountain Geyser	Rocket Geyser	

Riverside Geyser shows no short term trend relating it to Grotto Marathon eruptions or occurrences of Giant Hot periods. Riverside's intervals do show a slow wave-form over the course of the summer (page 306). Note that Riverside's intervals are near a peak for Giant's June 28 eruption, and are at a peak for Giant's September 12 eruption. This could imply an energy shift from Riverside's vicinity to Giant, which would explain Riverside's long interval at the time of Giant's eruptions. Note that Riverside's intervals were shortening slightly one month after Giant's September eruption.

This season's use of the term "Mastiff Function" follows the original definition where Mastiff (and sometimes Catfish) played strongly prior to Giant's eruption (Marler, pg. 127). Marler's definition of a "hot period" differs slightly from the present use of the term. His definition related to the rise in temperature (and level) of Giant and Mastiff. These pool's levels rise and fall today, but each rise is not necessarily followed by play from the platform vents. At present, a hot period occurs when one or more platform vents begin to play. Eruptions of Giant at present still occur during a hot period by either definition (i.e. high water levels exist in Mastiff and Giant as Giant begins erupting). Giant's past included periods of activity and dormancy. The year's eruptions suggest the return of a period of activity. The Washburn expedition named Giant in 1870 for the large volume of water expelled during an eruption (Whittlesey, pg. 62).

There is speculation that the September 18, 1963 eruption was soaped, thus some writers (including Marler) leave this eruption out of their descriptions. I assume at least one boxcar of soap would be required to upset the equilibrium of the 1,000,000 gallons of water which Marler estimates is expelled during an eruption.

The following eruptions have occurred since 1956. Note the latest information provided by Mike Keller.*

Date	Interval
9-18-63	7y 33d
9-9-78	14y 355d
9-27-82	4y 17d
10-12-84	2y 15d
8-20-86	1y 312d
9-12-87	1y 23d
6-28-88	300d
9-12-88	77d
*12-18-88	96d

The raw data (on Giant's and Grotto's activity) that was collected by all the thermal observers listed in the acknowledgements, Park Service naturalists, and myself appears on pages 344 - 349. I give special thanks to Scott Bryan for conducting a lengthy study to figure out Grotto's eruptive pattern during the month of June. His work formed the foundation on which my expanded observations and information to others was based.

GIANT "INDICATOR POOL"

The smoothed sinter forming the rim of this pool suggests the pool's level was above the present ground level and much more active in the past. At present the pool's usual level is about three feet below rim top, or about one or two feet above the floor of the pool. The indicator pool is connected to two other openings which all lie within a few feet of each other. Other nearby openings are filled in with sinter and vegetation.

No bubbling was ever observed. The pool's level did rise during all Bijou shutdowns to a point about one foot below overflow. There currently exists a pronounced stop to the reddish brown algae (or other deposits) that reach from ground level down the east wall of the vent to about one foot below ground level. This "line" is the high point reached by the pool's level. The pool's water level fluctuates in height, time and all other respects with the pool level in Mastiff Geyser. Turtle's pool level somewhat follows that of the "Indicator pool" and Mastiff. A damp boardwalk near the Giant Indicator Pool existed following the September 12 eruption; thus possible eruptive activity occurred from this pool during Giant's eruption (Stephens, pg. 5). The pool's level does not fluctuate any apparent amount as a result of Grotto's Marathon eruptions. I suggested the name Giant Indicator Pool since the pool responds to Giant and not to Grotto.

GROTTO GEYSER

I thank Scott Bryan for his devoted efforts in June which disclosed Grotto's eruptive pattern. I was then able to complete my own analysis of Grotto's behavior; after which I expanded that knowledge by linking Grotto and Giant together.

Grotto's eruptions were usually preceded by eruptions of Grotto Fountain and South Grotto Fountain Geysers. There was a short time in May and June when roughly 10% of Grotto's eruptions began without the other two Geysers. Now for some definitions of terms I've used to describe Grotto's behavior.

short duration eruption:	1 - 2 hours duration
average duration:	roughly 2 - 3 hours duration
marathon eruption:	13 - 23 hours duration

The duration of the delay between the initiation of Grotto Fountain's eruption and that of Grotto revealed the duration of the upcoming Grotto eruption and the length of the just finishing Grotto interval (Fig. 1, pg. 288). Carefully studying the graphs on pages 288 and 289 reveals the following: A short delay (under 5 minutes) meant that Grotto had erupted in the last 6 - 9 hours (Fig. 1, pg. 288), and that a short or average duration Grotto eruption had last occurred. A short delay also meant that the just-starting eruption could be a marathon eruption. Long delays (roughly 5 and 13 minutes) meant that a marathon eruption had previously occurred and the just finished interval lasted between 17 and 33 hours (Fig. 2, pg. 289). A long delay also meant that a short duration Grotto eruption (1 - 2 hours) was about to occur (Fig. 1, pg. 289).

Grotto's eruptions were preceded by increasingly larger and more voluminous bursts. These bursts were at first just visible and had little

water to them. After one or two minutes, bursts would be reaching the top of the sinter-covered tree stump (top of the cone also). This play would come and go for about one minute, when suddenly a large burst would fill the entire "grotto" to the top of the stump and the steadily climb from 20 to at times 50 feet in height. This initial burst (usually 25 - 35 feet) maintained its height for 5 - 10 seconds (at most) and then dropped back to individual and overlapping bursts from 4 - 20 feet in height for the remainder of the eruption. Toward the end of the eruption, play would have periods of more and less activity. The lesser play reached the top of the stump, and finally decreased to light spits and splashes. No splashing would then occur for several hours; after which hot periods occurred at random intervals. These hot periods were defined by rumbling and splashing within the underground vent along with occasional splashes above ground. The durations of the hot periods was several minutes and intervals varied from 10 - 40 minutes or more.

Short duration eruptions of Grotto most always occurred without activity by Rocket or Spa. Medium duration eruptions generally included one eruption of Rocket. Long duration (marathon) eruptions included none to two Rocket eruptions, eruptions by Spa, drops in Variable Spring and Marathon Pool, and the ceasing of the mostly constant play by Bijou Geyser. Grotto's marathon eruptions were related to activity in Giant Geyser and their intervals are graphed on page 287. This subject is treated in Giant's section of this report. Neither Grotto's marathon eruptions or Giant's eruption on September 12 caused any noticeable drop in Culvert Geyser's pool level. Intervals between Grotto "marathons" averaged 51 hours (Fig. 1, pg. 285). The number of short and average duration eruptions between marathon eruptions varied from 0 - 9, with an average of 3 (pages 344 - 349).

Grotto and Rocket were definitely affected by the August 24 earthquake located near the Old Faithful area (page 290). The short Grotto durations and intervals which occurred on August 24 are the shortest of each grouping in Figures 1 & 2, page 289. Grotto always stopped erupting as an eruption of Rocket went into full swing. Grotto was then quiet until Rocket's constant eruption reduced to individual bursts. At this time Grotto would begin churning and splashing and work its way back into a normal eruption. Either one geyser or the other was in steady play, with a short period (about

1 - 3 minutes) of overlapping half-hearted play by both geysers. Grotto remained a principle outlet for energy built up in Giant Geyser.

The extremely vague description of Grotto's activity in Marler's inventory leads me to believe this report may provide the first true picture of Grotto's activity (for a given time period) since the geyser was named by the Washburn Expedition in 1870 (Marler, pg. 100). I assume Scott Bryan has prepared a Grotto report also. Researchers should also consult his work. The Washburn Expedition observed 50 foot eruptions which lasted for 30 minutes (Whittlesey, pg. 67).

GROTTO "INDICATOR" POOL

The pool's level fluctuated in response to activity by South Grotto Fountain and Grotto Fountain. The pool level rose from about four feet below overflow to rim top as an eruption of Grotto Fountain neared. The pool level remained 1 - 3 feet below rim top much of the time. One foot oscillations in pool level were related to activity in South Grotto Fountain. The following scenario commonly occurred. The pool's level rose to 6 - 12 inches below rim top as Grotto Fountain lightly bubbled (its eruption was near). Then the previously quiet South Grotto Fountain would begin bubbling and bursting from 1 - 2 feet, and the pool's level would drop to one foot or more below rim top. Then South Grotto Fountain would quit bursting, calm followed for a few minutes and finally Grotto Fountain would begin to bubble and lightly overflow again. The pool's level began to rise during the calm period prior to bubbling in Grotto Fountain, and would rise back to 6 - 12 inches below rim top. One complete cycle of the pool level and related activity took about 40 minutes. Several cycles might occur with only one cycle rare, two cycles common, and three or more cycles not so common. Finally the pool level would rise to within four inches of rim top accompanied by 4 - 6 inch bubbling in Grotto Fountain. South Grotto Fountain would be empty and quiet at this time or on occasion water was visible with minute pulsing. The indicator pool's level then rose to within three inches from rim top for the start of many of Grotto Fountain's eruptions; though roughly 30% of the time the pool level rose to rim top, and on rare occasions actually minutely overflowed. As soon as Grotto Fountain began erupting, the pool's level would begin to drop, and by the time South Grotto Fountain began erupting (about one minute after Grotto Fountain began) the pool's level was dropping fast. The pool's level then remained down out of boardwalk view until the next start of Grotto Fountain's activity. I do not know the pool's response to eruptions of Grotto Geyser that were not preceded by an eruption of Grotto Fountain; these were rare occurrences that ceased in mid-June. The pool's

level served as good indicator of when Grotto Fountain's (and Grotto's) eruption might occur, with a pool level within one foot of rim top, a good sign that an eruption of the nearby geysers was within 2 hours. The closer the pool's level was to rim top, the closer the Grotto Group's eruption was.

Scott Bryan observed one eruption (several bursts) of the pool which reached above ground level. The pool level was 3 - 4 feet below rim top at this time. The pool level fluctuated in response to activity in Grotto Geyser in 1954, (Marler, pg. 106). Upper pool levels coincided with impending eruptions of Grotto Geyser. Since 1957 Marler noted the pool's level did not follow Grotto's eruptions as well, with periods of pool level fluctuations that sound similar to what is observed today.

GROTTO FOUNTAIN GEYSER

Light bubbling was the first sign that an eruption was less than two hours away. The strength of the bubbling gradually increased to 1 - 3 inches in height, then died away for a period of quiet. The cycle then repeated itself several times, with progressive increases in the height of bubbling. Light overflow to the northeast (not visible unless standing at the geyser) accompanied much of the taller (2 - 4 inch) bubbling. Bubbling finally reached 4 - 6 inches in height with a constant mini-eruption. This play could last for 1 - 2 minutes and then die away to no activity, or continue until the water column rose to 6 - 10 inches high. At this time the entire area around the geyser's vent (including the geyser's rim top) would be underwater. The steady 6 - 10 inch water column was the time I began counting an eruption. There was about 2 - 3 minutes of lesser play before this time. The water column then slowly climbed straight in the air with a beautiful feather shape, much like an eruption of Old Faithful. The water column rose directly up the eruption's center and fanned out in all directions to descend close to the dense primary output. Eruptive heights were 20 - 25 feet about the time Grotto Geyser began erupting. Grotto Fountain's eruptive heights increased to 30 - 40 feet (or more) during the first few minutes of Grotto Geyser's eruptions. The play's height remained constant for several minutes and then slowly decreased to a stop. There were usually no after-bursts following the end of constant play. The geyser was then calm and empty of water until one inch bubbling began prior to the next eruption.

The duration of Grotto Fountain's eruptions correlated to the duration of the Grotto Geyser eruption that was to follow (Fig. 2, pg. 288). An average duration of 9m 53s meant that a Grotto marathon (long duration) eruption was beginning. An average duration of 12m 43s meant that a 2 - 3 hour average duration Grotto eruption was beginning. An average duration of 19m 53s meant that this Grotto Fountain eruption was occurring at the end of a long interval following a Grotto marathon eruption, and that the Grotto

eruption just beginning was going to be of a short duration (1 - 2 hours). Fascinating, isn't it.

Grotto Fountain was first recorded as erupting in 1928 (Marler, pg. 95). The geyser had been dormant for up to 150 years prior to that time, based on the size of the trees that were killed by its rejuvenation. By 1947 the geyser preceded many of Grotto Geyser's eruptions (much like today). Much irregularity in the geyser's eruptions has occurred since the 1950's.

MASTIFF GEYSER

The geyser's two pools usually remained full to within 3 - 4 feet of rim top. Bubbling or light boiling was always present. Occasional, apparently random bursts from the southeast pool reached 1 - 4 feet above ground and puddled the area between Mastiff and Giant. Occasional bursts up to about 10 feet were noted by several observers. The north pool's level usually remained just below a shelf extending toward Bijou, and about three feet below rim top. During every 30 second or longer pause in the otherwise mostly constant play by Bijou, the pool level in both of Mastiff's pools rose. The longer the Bijou pause, the higher Mastiff's pool levels rose. Mastiff's northwest pool was calm during these rises in pool level, rather than the usual constant mild bubbling. This may imply that growth of larger steam bubbles was raising the pool's level and at the same time reducing the number of smaller bubbles that reached the pool's surface. A Bijou pause of about 4 - 6 minutes was required for Mastiff's northwest pool to overflow its rim to the northeast and southwest. During these periods of overflow (which immediately preceded a major hot period by Giant's platform vents) Mastiff's southeast pool would not be overflowing, rather small spikes of water about one foot high (at most) would jump out of the pool. Mastiff's pool level sometimes rose within a foot of overflow, only to drop and be followed by Bijou reinstating its constant play. During a Giant hot period, Mastiff's pool dropped several minutes into the hot period. Play by Bijou then followed the drop in pool level. Close observations of Mastiff's southeast pool was risky because of the random bursts expelled from this pool.

During Giant hot periods, Mastiff's overflow (from the northwest pool) slowly worked its way west of the geyser and finally reached the boardwalk west of Catfish and Giant. Occasional strong overflow was described by Lynn Stephens and Mary Ann Moss as "like a Great Fountain overflow". Water at least two inches deep flowed from Mastiff during the hot period which

immediately preceded Giant's eruption on September 12 (Stephens, pg. 1). This eruption of Giant was a Mastiff function. Mastiff was surging to 12 feet about four minutes prior to Giant's eruption. Within one minute of that time Mastiff's eruption reached about 50 feet in height. This eruption was from Mastiff's southeast pool. Lynn observed Mastiff erupting to "a height approaching 100 feet" during the first few minutes of Giant's eruption. Mastiff was off 24 minutes into Giant's eruption.

Two hours after the June 28 eruption of Giant, Mastiff's southeast vent was producing a wet gurgle deep inside. The northwest vent was quiet and the bottom of the vent could be seen "about 20 - 30 feet down"; I noted it was an "impressive depth". 18 hours later Mastiff was steaming, with no visible water. Mastiff was producing occasional light spits 38 hours have the September 12 eruption (Stephens, pg. 7).

Mastiff was first observed erupting in 1877 (Marler, pg. 159). The 20 - 30 foot eruption preceded an eruption of Giant Geyser. Periods of activity by Mastiff have come and gone since then. The last Mastiff function period ended in 1952. In 1951, Mastiff erupted to heights "comparable to Old Faithful" and sometimes was joined by eruptions of Catfish to 50 or 60 feet.

"MARATHON POOL"

The pool's level was usually about six inches below rim top, clear, and calm. The only fluctuation from this level was during a Grotto marathon (long duration) eruption. The pool's level would still be normal (near rim top) about nine hours into Grotto's marathon eruptions. The pool's level would be about two feet below rim top with constant 2 - 4 inch boiling, about 10 hours after a 16 hour Grotto eruption. The pool level would be up to one foot below rim top with constant mild bubbling, about six hours prior to the next Grotto eruption. At this time Variable Spring would have already recovered from Grotto's marathon eruption. Pool boiling two feet below rim top was observed 30 hours after one marathon eruption.

Marathon Pool's level dropped after Variable Spring's pool level dropped (during marathons). Marathon's pool then rose after Variable's pool recovered. Two small pools about 20 feet northwest of Marathon Pool (directly across the footpath) showed no change in pool level or degree of boiling in response to Grotto Marathon eruptions. The spring just uphill and behind the benches at Riverside Geyser (Bench Spring) was not affected by Grotto's Marathon eruptions.

OBLONG GEYSER

The geyser's pool was usually full and overflowing, with a pool level 2 - 3 inches below most of the rim. Periods of increased overflow accompanied pool levels about one inch from overflowing the entire rim. These upper pool levels lasted 1 - 2 minutes and included water flow leaving the southwest end of the pool, after which it turned due west and flooded down several sinter ledges. This flow looked like water flowing down stairsteps. Following a period of stairstep flow, the pool level dropped back to 2 - 3 inches below rim top and trickle flow returned. Some bubbling occurred during these upper pool levels, and possibly at the lower levels also. The upper pool levels also nearly submerged a group of islands within the main rim and just north of the geyser's vent(s). Intervals between periods of overflow were usually 40 - 50 minutes, and sometimes about 20 minutes. A 20 minute interval did not necessarily mean an eruption was close. After many hours of overflow, the runoff channel west of the geyser would be wet as far west as the channel reached. Slight signs of running water were present in this region. This was a good sign that an eruption was near.

Finally during one of the periods of stronger overflow, strong thumps would be felt underground and the pool would then overflow the entire rim. On other occasions the thumps followed the overflow. The thumps were strongest just north of the geyser at the edge of a small group of trees. The pool overflowed the entire rim for about three minutes, followed by a slowly growing boil. Eruptions consisted of individual and usually overlapping boils about 4 - 15 feet wide and 5 - 25 feet high. One eruption of Oblong reached the top of the trees north of the geyser when viewed from Grand; thus an eruption of about 40 feet occurred. The strength of the eruption came and went. Half a minute of 5 - 10 foot boils did not necessarily mean the eruption was ending. The strength of activity eventually decreased, along with a dropping pool level so that boils reached only to the geyser's rim top.

The boiling finally subsided and a pool level about 4 - 5 feet down was all that remained following an eruption. Bubbling was still present at this time. The pool level took 2 - 4 hours to recover to within six inches of rim top.

These initial eruptions of a possible series of eruptions lasted an average of 7 minutes (Fig. 1, pg. 291). The second eruption of a series followed in an average 2h 14m (Fig. 2, pg. 291). These eruptions usually occurred from a pool level near rim top, though on occasion from a level 1 - 2 feet down or an overflowing pool. Second eruptions of a series were generally stronger than the first and had a longer average duration of 8 minutes. The eruption form was the same as the initial eruption. Third eruptions of a series followed the second after an average interval of 35 minutes, and had durations of only 6 1/2 minutes. Now the pool took 3 - 4 hours to recover to near rim top. During the first half of the summer there was only one eruption per series. From August on there was the possibility of a second or maybe even a third eruption, though the single eruptions were still most common. The average interval between observed series (start to start) was 25 hours (page 292). "Known" intervals were visually obtained or obtained through use of markers, and their average was 26 hours. Note the random bell-shaped curve to the intervals, and yet I assume that some connection exists with Giant, but I have no proof so far.

Oblong continues to exhibit the irregular intervals noted since 1968 (Marler, page 166). Prior to that time intervals averaged 2 - 3 hours on a much more regular basis. Marler may be correct in suggesting that Oblong's changes resulted from the driving of piles for the overpass 1/2 mile away which resulted in a steady outflow of water. Oblong's intervals became consistently irregular a few weeks after the piles were driven. Oblong's eruptions in 1878 were noted as a small version of Giantess' eruptions. This is still true today.

PURPLE POOLS

As of November 4, no eruptions of any of the three Purple Pools had occurred since the eruptions observed on October 16 & 17, 1987 (Landis, pg. 79). These eruptions included an initial eruption by all three of the Purple Pools, followed by many eruptions of South Purple Pool to heights of 10 - 35 feet. These eruptions were the first ever observed by these features during the Park's history.

South Purple Pool remained in strong overflow for nearly the entire summer, except for a few hours following eruptions of Giant. At this time no overflow occurred since the pool's level was about 4 - 6 inches below overflow. The strong overflow for most of this summer was visually identical in discharge to the increased overflow which occurred two months prior to last year's eruptions. South Purple Pool was calm and blue-green clear during all observations. The small vent about 10 feet southeast of South Purple Pool received runoff from Beauty Pool while Beauty remained in overflow.

East Purple Pool's level remained 1 - 2 feet below overflow with constant boiling. No definite drops in pool level occurred following eruptions of Giant. Boils reaching 1 - 2 feet above ground level and lasting 2 - 3 seconds were seen twice this summer, from Giant Geyser.

North Purple Pool's level remained about one foot below rim top with strong 6 - 12 inch constant boiling. This pool's boiling was always stronger than the east pool's. The North Pool's eruption last year discharged a rock weighing 30 - 40 pound a distance of about 10 feet from the pool. No definite drop in this pool's level followed eruptions of Giant.

The 3 - 4 inch diameter fallen trees which were moved several feet by the runoff from East Purple Pool during last year's eruption burned during this

year's second fire storm on September 9. Occasional overflow has occurred from North and East Purple Pools in the past (Marler, pg. 168). South Purple Pool has usually overflowed during all past observations, and continues to do so today.

ROCKET GEYSER

The geyser was basically quiet between eruptions of Grotto Geyser. At these times Rocket's pool would be 3 - 5 feet below rim top. Bubbling, boiling, light bursting, and an occasional calm occurred in Rocket between Grotto's eruptions. Rocket produced 1 - 5 foot bursts at the initiation of Grotto's eruptions. Rocket then splashed on occasion during most of Grotto's eruption duration. Taller and taller bursts preceded Rocket's eruptions by about 30 minutes, with burst heights of 4 - 10 feet above the top of the cone. These bursts eventually became full vent very wet bursts. Finally a sustained burst to 5 - 10 feet above the cone poured water in every direction; followed by a quick climb to 20 - 40 feet above ground, sometimes more. This height was maintained for 5 or 10 seconds at most and then dropped back to a 15 - 25 foot (above ground) steady eruption. Eruptive heights varied somewhat during eruptions, but the steady play continued. The constant play eventually dropped to 2 - 6 feet above the top of the cone, and finally became individual bursts. I noted this time as the end of an eruption. The individual bursts then continued for 1 - 2 minutes, with some of them reaching 20 feet above ground. The geyser then went back to small individual splashes for the remainder of Grotto's eruption, or occasionally a second Rocket eruption occurred.

The time Rocket would erupt after the start of Grotto's eruption averaged 2h 17m (Fig. 3, pg. 293). The duration of the concurrent Grotto eruption did not appear to related to the time that Rocket erupted, except in the case of short Grotto eruptions where only one Rocket eruption occurred. If Rocket erupted a second time, it did so about two hours after the first eruption (Fig. 3, pg. 293). Rocket's eruption duration averaged 8m 35s (Fig. 1, pg. 293). Short duration and short intervals between Rocket's eruptions coincided with earthquake activity on August 24 (pages 290 & 293) with a record 19 minutes between eruptions.

Other than earthquakes, the only times Rocket had two eruptions in a row was during Grotto Marathon (long duration) eruptions. When this happened, Spa Geyser's eruption was always postponed. I observed the other extreme when Spa would begin erupting about three hours into Grotto's eruption, and no Rocket eruptions occurred. Generally Rocket erupted once and Spa would be erupting about the time there would have been a second Rocket eruption.

The gradual increase and decrease in Rocket's activity before and after an eruption were almost mirror images of each other. If an observer left for 10 minutes and Rocket erupted while they were gone, the observer would return to the same activity they had left and swear there had not been an eruption. Grotto's activity always decreased to light splashing, and then Rocket's activity would pick up and finally Rocket would erupt. Grotto's activity would quiet down to almost none within one minute of the start of Rocket's eruption, and remain almost dead during the eruption. Grotto's activity would resume during Rocket's period of individual bursts immediately following Rocket's eruption. Rocket was more active this year than last year, and yet Giant was more active this year than last year. Thus energy was not altogether diverted to Giant over the summer.

Past references describing Rocket's eruptive height, duration, etc, are very much like what was observed this year (Marler, pg. 119). The minor eruptions Marler describes are the individual small bursts I've mentioned earlier. Rocket was named in the late 1880's, possibly for its Rocket-like eruptions (Whittlesey, pg. 133).

SOUTH GROTTO FOUNTAIN GEYSER

Pre-eruptive bubbling and bursting from South Grotto Fountain caused Grotto's Indicator Pool level to drop, and also delayed Grotto Fountain's eruptions. A full description of this pre-eruptive activity is in the Grotto Indicator Pool section of this report, on page 132).

South Grotto Fountain always began erupting after Grotto Fountain began its eruption, and the average time between the two eruptions was 1m 25s (Fig. 2, pg. 294). There was a slight tendency for a short interval between the two geyser's eruptions to relate to a long eruption duration by South Grotto Fountain (page 295). South Grotto Fountain's eruption duration showed the same relationship as Grotto Fountain to the upcoming duration of Grotto Geyser. Long Grotto eruptions were preceded by a short eruption of South Grotto Fountain (Fig. 1, pg. 294), and at the other extreme short eruptions of Grotto Geyser were preceded by long eruptions (averaging 21 minutes) of South Grotto Fountain. Eruptions of South Grotto Fountain were always longer than Grotto Fountain's eruptions.

The earliest positive reference to South Grotto Fountain is in 1941 with play to 10 feet that ended two minutes after Grotto Fountain's eruption ended (Marler, pg. 96). An earlier reference in 1932 talks about a second vent playing to six feet; this could be South Grotto Fountain. I suspect that South Grotto Fountain is dormant when Grotto Fountain is, since they both show a connection together via activity in the Grotto Indicator Pool.

Eruptions consisted of overlapping 1 - 6 foot bursts from several vents. Eruptions were always somewhat messy with water spurting basically up but seemingly all over the place. Activity fluctuated somewhat during an

eruption. Short durations of activity (usually under one minute) occurred at random times with two hours of Grotto Geyser's eruptions and occurred at most any time during Grotto's eruptions. This play was usually from 1/2 - 3 feet.

SPA GEYSER

Spa's pool level was 3 - 4 feet below overflow at the start of Grotto Geyser's eruptions from late April through mid-August. Spa's pool level would then fluctuate up and down to within 1 - 2 feet of overflow during the first 2 - 4 hours of Grotto's eruption. Rocket Geyser would usually play during this time. Within one hour following an eruption of Rocket, Spa's pool would be in overflow. Spa's eruption series began 1 - 3 hours after Rocket's eruption, or about 3 - 4 hours after Grotto Geyser's eruption began (Fig. 5, pg. 296). Grotto evidently needs to erupt 3 - 4 hours before Spa can erupt. Occasionally Rocket would not erupt, and Spa then erupted within three hours of the start of Grotto's eruption (Fig. 5, pg 296).

Spa's eruptions began during an overflowing pool. Small boils developed during the first hour of overflow. These boils reached about one foot in height and lasted 2 - 5 seconds. After usually at least 30 minutes of this smaller activity, larger bursts developed. These bursts reached 5 - 35 feet in height, and shot from the geyser with no warning. This form of eruption always startled the visitors nearby. On one occasion, a larger burst wetted the pavement 20 - 25 feet northwest of the geyser. There was either a single burst, or several individual (usually) or overlapping bursts lasting an average of 9 seconds (Fig. 1, pg. 296). Intervals between smaller bursts from 6 - 20 feet in height averaged 7 minutes, and intervals between bursts 20 feet or higher averaged 16 minutes (Fig. 3 & 4, pg. 296). There was usually no overflow between bursts. Momentary overflow occurred with any of the larger bursts. The duration of a series of eruptions was about 5 - 6 hours (Fig. 2, pg. 296). Eruptive activity decreased slowly to only occasional 1 - 3 foot boils, and finally to a non-overflowing (though still full) pool about 30 - 60 minutes after an eruption; followed by fluctuations as the pool level dropped. Note that Spa's build-up of activity prior to an eruption series was roughly symmetrical to the decrease in activity following an

eruption series. This pattern was also noted in Rocket Geyser, and fits the close relationship between Rocket and Spa that was previously discussed.

By late August, Spa had developed a major shift in its activity. Spa's pool would be in overflow prior to Grotto's eruptions. Spa's pool level then dropped to 1 - 3 feet below overflow about an hour into Grotto's eruption. Rocket occasionally exhibited 3 - 4 foot full vent bursts around two hours into Grotto's eruption, but would not erupt. Spa's pool would then be in overflow about four hours into Grotto's eruption, with an eruption series finally occurring. On other occasions Spa would be 4 - 6 inches below overflow or overflowing when Grotto erupted, after which Spa's pool level would drop (about 30 minutes into Grotto's eruption). Rocket would then have an eruption (2 - 3 hours into Grotto's eruption) and Spa would then overflow about 10 minutes after Rocket's eruption. No eruptions of Grotto Fountain preceded some eruptions in late September. I don't know if this related to the change in Spa's activity in late August.

Spa's overflowing prior to Grotto's eruptions did not only occur prior to Grotto marathon (long duration) eruptions. Eruptions of Spa were noted last year with some bursts reaching about 40 feet, and usually lasting just long enough to see the burst shoot up.

Spa's activity has been highly irregular in the past with periods of overflow of varying length (Marler, pg. 123). True eruptions were first noted in the 1950's with only boiling and overflow observed before this date. Spa was named in 1887, possibly for medicinal springs at Spa, Belgium (Whittlesey, pg. 145).

TURTLE GEYSER

No eruptions were observed this summer. Turtle's only activity was several minutes of overflow during Giant's major hot periods. Overflow began about two minutes after the first platform vents began erupting. Turtle's overflow occurred primarily to the southeast, with additional overflow to the west-northwest on some occasions. Overflow stopped prior to the end of play by Giant's platform vents.

Turtle's pool level pulsed up and down during pauses in Bijou Geyser's otherwise constant play. These fluctuations had an amplitude of about six inches with a pool level about 2 - 3 feet below overflow. Water was visible in Turtle's vent during most observations.

During the 1950's, play by Giant's platform vents (a major hot period) was always preceded by overflow from "a side vent on Turtle's cone" (Marler, pg. 150). Eruptions of Turtle up to 20 feet in height were observed during some hot periods. I have not observed a side vent on Turtle's cone; overflow only occurred from the top of the cone. Possibly the side vent sealed itself off during the past 30 years of infrequent activity by Giant.

"VARIABLE SPRING"

The spring was in overflow to the east during most observations. Light bubbling was also present at times. The pool was usually clear. Runoff from Grotto's eruptions flowed into the pool, as well as around the southern end of the pool. The pool's level dropped one inch at most during Grotto Geyser's 2 - 3 hour average duration eruptions. The pool's level dropped 6 - 8 inches during Grotto's long duration (Marathon) eruptions. The spring's pool level was lowest at the end of Grotto's long eruptions and remained at this level for several hours. Increased bubbling occurred at these low pool levels, and no overflow from the pool occurred at this time. The spring's pool level would be back up to within one inch of overflow 5 - 7 hours prior to the Grotto eruption which followed a marathon eruption.

The pool levels in Variable Spring and Marathon Pool both dropped during Grotto marathon eruptions. Variable Spring's level dropped prior to Marathon Pool's level, and Variable Spring recovered before Marathon Pool did. The just-mentioned fact was useful in determining how far along a marathon eruption was, as well as how close Grotto's follow-up eruption was (following a marathon).

Variable Spring's pool was cloudy after many Grotto marathon eruptions. The pool's level dropped about two feet after eruptions of Giant Geyser. Following an eruption of Giant, the pool required 12 - 17 hours to recover to overflow and took 15 - 20 hours to refill to rim top. The pool would be murky during this initial overflow.

"BENCH SPRING"

The spring was always clear, and produced periodic overflow. The question had been raised as to whether the fluctuations of this spring's level coincided with eruptions of Riverside Geyser. Overflow from the pool occurred every 7 - 12 minutes. Maximum overflow lasted about 2 - 3 minutes. The spring's overflow exhibited long-short interval cycles, consistent interval cycles, periods of stronger than normal overflow before and after eruptions of Riverside Geyser, no stronger periods of overflow, and a much wider interval range than Riverside Geyser. The spring's interval average was about 2 1/2% of Riverside's interval.

All of the above observations show that as of this date, the spring exhibits no statistical or physical connection with Riverside Geyser. The spring's periodic overflow did not appear related to Grotto marathon eruptions.

CULVERT GEYSER

The geyser exhibited constant bubbling at the south end of its pool. This bubbling was in fact the discharge from the hot spring buried under the road about six yards southeast of Culvert. Discharge from this spring is piped to the south end of Culvert's pool. Culvert itself produced occasional bubbles from its large subsurface vent. Overflow was to the north of Culvert, was constant, and supported a thick algae bed. One or several typically destructive visitors pushed a large ryolite block (about 3 x 2 x 2 feet) into Culvert in early June. This block originally formed part of the masonry rim built along the east (roadside) wall of the geyser's vent. The block came to rest on a shelf east of (though close to) Culvert's main vent.

Early in June, steam began being expelled from numerous locations between Culvert and the buried spring southeast of Culvert. Evidently the buried pipe was leaking. The buried spring blew out on June 23 (see Persistent Geyser). Culvert's pool level dropped several inches following the blowout nearby. Culvert's pool was then calm, murky, about 2 - 3 inches below any overflow, and heavy silting was present for seven yards down the northern runoff channel. The extensive algae bed north of Culvert died. Culvert's pool eventually cleared, though no overflow occurred the remainder of the summer.

Periodic 1 - 2 inch fluctuations of Culvert's pool level occurred, as originally noted by Mary Ann Moss. These fluctuations coincided with similar activity in Square Spring and Persistent Geyser (see page 297). This figure shows that Culvert's pool rises quickly just as Square Spring's pool level reaches its maximum height, though Square Spring's rise is slower than Culvert's. Also note that Persistent Geyser's pool level rises quickly about the time Culvert's pool level rises, and then drops before Culvert's pool drops; both of which occurred quickly. The rise in Culvert's pool level came within 1 - 2 inches of its previous overflow level, though no true overflow occurred in the original (northern) runoff channel.

The three pool's fluctuations show a clear connection between these features. Culvert did not show any noticeable changes during Grotto's marathon eruptions or Giant's eruption on September 12 (Stephens, pg. 6).

Culvert was a hot spring until a nearby spring (Persistent Geyser) was buried during road construction (Marler, pg. 87). Energy from the buried spring then shifted to Culvert, which then produced a constant 2 - 4 foot eruption. Culvert's steady eruption ceased sometime after 1970, since Marler makes no mention of changes in eruptive activity.

FAN AND MORTAR GEYSERS

The two geysers continued to erupt together throughout the summer. Both features were active during all of 1987 and eruptions were observed often enough during the '87 - '88 winter to suggest that eruptions have occurred on a regular basis from June '87 through November '88. Jens Day observed many of this summer's eruptions which provided me with new insight into the two geysers' behavior.

Hot periods occurred between eruptions which provided an indication of the geysers' readiness to erupt. During a hot period, first Fan Geyser and then Mortar Geyser discharged water. Fan Geyser's hot period included play by four of its vents (River, Top, Gold, Angle) (see map on page 338). These vents produced minor bursting from inches to about two feet in height. Intervals between River Vent's activity was commonly timed (start to start) as one indication of the geyser's ability to erupt. "River Intervals" of 10 - 20 minutes occurred 5 - 15 hours after an eruption, and intervals of 60 - 90 minutes occurred just prior to an eruption. In both cases liquid output (bursting and overflow) occurred during about half the interval. This pattern was noted last year (Landis, pg. 74), and Jens Day noted the trend continued this year. River Vent's play during a hot period reached 2 - 6 feet (and more) into the Firehole River. Play by the other three vents usually started after River Vent's play, with heights of inches to about two feet observed. Jens Day noted that the longer the delay between the start of River Vent's play and play by Gold Vent, the closer an eruption was. Delay's of 15 - 20 minutes were a sign that an eruption might occur during the present hot period, or probably within a few hours.

Play by Fan Geyser's vents was well underway before Frypan Vent began to play. Frypan Vent then continued to spit and sizzle (like water on a hot frypan) as Fan's activity decreased to none and Mortar Geyser's two vents became active. Lower and Upper Mortar were then active for awhile, after

which a quiet period occurred prior to the restart in play by Fan's vents. Lower Mortar was the most active of Mortar's two vents with constant bubbling along with some splashing from 1 - 3 feet in height. Upper Mortar was usually quiet, though on occasion 1 -4 foot bursts were produced. According to Jens Day, these bursts showed a tendency to occur about 12 hours before either an eruption or a period of increased activity in the two geysers.

Intervals between hot periods uniformly increased prior to some eruptions (page 298); otherwise intervals fluctuated with no consistent pattern (page 299). Eruptions were usually initiated by Fan Geyser, and occasionally by Mortar Geyser. When Fan initiated an eruption, it occurred during Fan's portion of a hot period. Fan's vents would begin a "usual" hot period with an eruption occurring about 10 - 30 minutes into the hot period. Many of this year's eruptions began "late" into a hot period (20 - 30 minutes). This was a change from last year when eruptions generally began 10 - 15 minutes into hot periods. Many of this year's eruptions occurred during "weak" looking hot periods which produced only light overflow from Fan's vents. Several observers walked away from this year's "weak" hot periods only to have the geysers erupt 5 - 10 minutes later. Pauses in River Vent's play occurred prior to all eruptions, as well as occasionally between eruptions. Thus like last year, a pause did not mean an eruption was sure to follow (Landis, pg. 74). Fan-initiated eruptions began with surging 1 - 2 foot spouting from at least two of Fan's upper vents (Top, Gold, Angle). After 2 - 3 minutes, this surging play would reach 3 - 4 feet in height. At this time observers nearby would smile or jump up and down, yelling and screaming, because all knew an eruption was about to begin. Eruptions rose quickly from Fan's vents, with Mortar's eruption following close behind. The geysers' lived up to their fame with water erupting in every direction from Fan, and strong columns occasionally shot from Mortar. Fan's Grand Canyon vent would send eruptions about 100 feet over and beyond Spiteful Geyser, to the northeast side of the fork in the footpath leading to the restrooms and Morning Glory Pool. On one occasion, Fan's spray reached east of Norris pool. Mortar's eruptions began with a solid thump which was followed by a 30 - 60 foot (occasionally more) eruptions. All of the two geysers' eruptions included 4 - 7 separate bursts, like Grand Geyser. The series of bursts included an initial long burst lasting 15 - 17 minutes, followed by a decrease in burst duration and then another increase in duration (pages 300 & 301). All bursts

included a mix of liquid and steam phases. The strength of an eruption decreased gradually over the 40 - 45 minute average total eruption duration. Billowing clouds of pulsing steam followed the end of each burst, and followed the end of all eruptions. Every possible viewpoint should be tried, as each one offers a unique view of the two geysers' play. Fan's vent buried under the road north-northeast of Spiteful Geyser expelled water during every eruption. Mortar-induced eruptions began during Mortar's portion of a hot period, and occurred during a period of strong surging by Upper Mortar (Jens Day).

Eruption intervals varied from 75 - 394 hours (about 3 - 17 days). Page 302 shows an initial period of long intervals was followed by a period of short intervals which gradually increased in length and then jumped back to "short" again. All intervals on page 302 were verified with markers on both Fan and Mortar. The average interval was 151 hours (6 1/2 days) for the summer (Fig. 1, pg. 303). There was talk again this summer that most eruptions occurred at night. There were times when several eruptions in succession did occur at night, but Fig. 2, page 303 shows that eruptions occurred at random times during the day. As suggested by Ted Koch, a Department of Fish Wildlife and Parks biologist, a definite diurnal cycle to the temperature of the Firehole River did occur, with cooler temperatures in the morning and warmer temperatures in the afternoon prior to sunset. River level fluctuations were not diurnal, rather changes required 1 - 3 weeks to amount to much. Note that Fan and Mortar's longest interval occurred during the Firehole River's high spring water level. During this time the two sandbars near Riverside Geyser were completely submerged. Fan Geyser's River Vent has numerous outlets over a wide range of heights above the Firehole's usual summer level. I would not be surprised if some of River Vent's openings are submerged by the Firehole's high water levels, and thus serve as inlets for cold water to enter Fan Geyser. Spiteful Geyser's pool level dropped several inches following some eruptions of Fan and Mortar.

Eruptions of Fan and Mortar were first observed in 1871 (Marler, pg. 67). At that time the geysers played more frequently than they do now, with eruptions several times a day. Early observers found themselves "quite weak from excitement" after witnessing an eruption in 1878 (Whittlesey, pg. 54). By 1920, both geysers were considered dormant. A noted increase in activity occurred in 1969 and 1970 with 28 - 32 eruptions observed from

May - October of each year. This year there were 31 eruptions for the same time span, so activity at present remains about the same. Veteran observers note that eruptions over the last dozen years or so occur actively for 1 - 3 years, followed by dormancy for several years, and then another rejuvenation. There is current speculation that Fan and Mortar will enter another period of dormancy soon, possibly over the 88 - 89 winter. We'll see. All accurate records in the past note both geysers erupting together, never separately. This trend continued last year and this year.

LINK GEYSER

No eruptions were observed this year or last. Current activity amounts to constant overflow from a clear pool, accompanied by 6 - 12 inch constant boiling. Occasional 1 - 3 foot boils were observed, more-so last year than this year. Periodic stronger overflow occurred on a semi-regular basis. Stronger boiling does not necessarily occur with every overflow. No definite connections exist between Link and Fan and Mortar. In the past, strong eruptions have thrown 300 pound chunks of sinter from Link's vent (Marler, pg. 88). The geyser is obviously tearing itself apart.

MORNING GLORY POOL

Slight overflow leaves the northwest rim of the pool. Algae grows over most of the pool's walls. The pool continues to receive a daily dose of death, mostly in the form of pennies. Some big spenders throw in dimes and quarters. The pool's scalloped sinter rim was completely removed by early visitors to the Park (Whittlesey, pg. 102). Tossing in coins became a popular pastime in the 1930's (Marler, pg. 80). A common question today is "Where is Morning Glory Pool?" The constant attention the pool receives hopefully helps slow the destruction of other features in the basin. A little public awareness concerning the vandalism of hydrothermal features would be a good idea, but I see little interest in promoting this form of education. Early visitors to the park destroyed the original sculptured appearance of most all the geysers and hot springs (Marler, Whittlesey). The park's present visitors are busily sealing off nature's work forever.

NORRIS POOL

Several thermal observers said this pool is the Upper Geyser Basin's Norris Pool. Grass grows down to the pool's water line. The pool itself is partially covered with bright green algae. More algae grew on the pool's surface this year than last. The pool did not show any relationship with Fan and Mortar Geysers. Norris Pool's location does suggest that it and Fan Geyser may lie along the same fault zone.

The two mudpots just south of Norris Pool do not appear to be connected with Fan and Mortar. The mud in these mudpots is very thin.

"PERSISTENT" GEYSER

I suggest this name for the hot spring that has emerged from the road near Culvert Geyser for the second time. The original unnamed spring was buried under the road prior to 1954 (Marler, pg. 87). The hot spring emerged through the roadbed in 1954, leaving a hole big enough for a car to fall into. The hot spring was again buried, only to emerge again in 1988. The spring's past record and present, constant boiling suggests the name Persistent Geyser.

On June 23 of 1988, the spring blew out a 1 1/2 x 2 foot hole about 6 1/2 yards south-southeast of Culvert Geyser. Several small stones weighing about one pound each were thrown from the new vent. Strong thumping was felt north and east of "Persistent Geyser" the morning after the vent opened up. Bursting reached heights of 2 - 15 inches at that time. Persistent's vent had grown to 4 x 5 feet by August 5, and remained this size through November 15. The pool remained clear and bubbling strongly during all observations. Persistent's pool level had risen 2 - 3 inches between August and November. The upper pool level was about six inches below the west rim of the pool. As originally noted by Mary Ann Moss, Persistent's pool level fluctuates with Culvert Geyser's and Square Spring's pool levels as shown on page 297. Note here that Persistent's pool level rises (1 - 2 inches) quickly at about the time Culvert's pool rises. Persistent's pool level then drops before Culvert's pool level drops. The underground pipe connecting Persistent and Culvert still flows water, thus it is hard to say if one feature is affecting the other, though both pool levels rise after Square Spring's pool begins to slowly rise. Culvert's pool level did not fluctuate or show any alteration due to the Giant eruption on September 12 (Stephens, pg. 6); thus I don't believe there is a connection between Persistent Geyser and the Grotto/Giant group.

The November snowfalls outlined Persistent's location relative to the new surface vent. Persistent blew out along the western edge of the heat source which extents about 10 - 15 feet east of Persistent's pool. The strong thumping evident at the time the vent reopened has subsided, though the crater continues to slowly grow in size.

RIVERSIDE GEYSER

The geyser continued to exhibit fountain-type eruptions on a very consistent basis throughout the summer. Just-visible bubbling occurred in the main vent 10 - 20 minutes prior to the first overflow. No true pool existed at first, but did exist 2 - 5 minutes prior to overflow. Overflow began through a channel leading from the main vent to the pool's rim, thus a full pool was not required for first overflow. The geyser's pool was full and clearly visible about 10 minutes into overflow. At this time, occasional 6 - 12 inch bursts occurred. Cyclical bursting reached 1 - 3 feet in height about 20 minutes into overflow. Periods of stronger boiling were now followed by a short period of no boiling and at times no overflow. The geyser's east vent began its play about 40 - 50 minutes into overflow. This vent's play reached about 6 - 10 inches in height and remained constant throughout the cyclical activity in the main vent. The east vent's play was a reliable indicator as to how far along the pre-eruptive overflow was. Very strong overflow occasionally occurred at about the six-hour interval mark. This overflow spilled over most of the geyser's rim. Note that this overflow surge occurred about the time of a Riverside short interval. Another possible occurrence, rather than an overflow surge, was several seconds of 1 - 4 foot bursting from the geyser's upper vent. This bursting usually only occurred leading up to an eruption, or at the "short interval" mark. I never observed upper vent bursting and an overflow surge together at the six hour mark without a short-interval eruption following. Sometimes no bursting or surging overflow occurred at the short interval mark.

If no eruption occurred at a short interval, then overflow returned to normal and the cyclical bursts and calm returned to the main pool. Bursting then tended to increase in height and duration prior to the "normal" interval eruption. Occasional upper vent bursts and surges of overflow occurred between a "short" and "normal" interval. Every normal interval eruption was preceded by 2 - 3 foot bursts from the upper vent about 5 - 15 minutes

prior to the eruption. these bursts were a giveaway that the eruption was very near. Note that (as usual with geysers) it helped to know how far along the interval or overflow was. On one occasion all overflow stopped about four minutes prior to the eruption. This pause lasted under one minute.

Finally the main vent produced constant 2 - 3 foot bursting for 5 - 10 seconds along with overflow over the entire rim, and then the eruption began. The water column poured into the Firehole River as its height increased. Two sandbars in the middle of the river lie on either side of where the eruption descends into the river. The upper vent gave a short (under 20 seconds) continuous eruption at the start of the main eruption, followed by individual bursts with pauses. The short eruption reached 5 - 10 feet in height. The east vent would be "off" about 10 minutes into the eruption. The upper vent's occasional bursting continued at this time. Steam was visible spewing from a location about 10 feet southeast of Riverside's pool, just uphill from the geyser. This steam location, the main vent, and the east vent formed somewhat of a right triangle with the main vent and the steam vent on the triangle's hypotenuse.

Eruptions reached heights of about 80 feet. Stronger eruptions produced a buzzing sound during the first few minutes of the eruption. The sound was like that from a circular saw cutting wood, but at a lower pitch. I assume the sound resulted from friction between the water and the walls of the geyser's vent. Eruptive heights slowly decreased as the eruption progressed, remaining at 30 - 40 feet for much of the eruption. I concluded eruptions at the time when water ceased to sprinkle into the river. Rolling, billowing steam followed for 10 - 15 minutes.

Durations of overflow prior to eruptions averaged 106m overall, and durations of overflow prior to "normal" intervals average 114 minutes (Fig. 2, pg. 304). The shorter overflow durations relate to short interval eruptions. The average eruption duration was 21m 40s (Fig. 1, pg. 304), regardless of whether a short or normal interval preceded the eruption. Eruption intervals averaged 6h 48m and continues to show the bi-modal behavior this geyser has been noted for (page 305). Thus 17% of observed and calculated intervals were short intervals. The short intervals tended to occur in groups over 1 - 2 week time spans (page 306). Note that the

duration of overflow remained fairly consistent throughout the summer, even though a slow change in the approximate average interval occurred.

As food for thought and future observations, note on page 306 that Riverside was in a "normal" interval mode for each of Giant's two eruptions this year (June 28 and September 12). Also note that the intervals were at or near an overall peak for both of Giant's eruptions, and that Riverside's intervals began to shorten about the time of Giant's second eruption.

Riverside's consistency is shown by the nearly identical descriptions that G. Marler and I have written (Marler, pg. 107). I did not read Marler's report until after writing mine. The geyser's present interval average is in the middle of past interval averages. The duration of overflow is about the same. The east vent plays longer today than in the past. Even the period of short intervals (about one week) remains much the same from the past to the present. Riverside was named in 1871; confusion continued for years afterwards as to which Geyser was Riverside (Whittlesey, pg. 131).

SPITEFUL GEYSER

No eruptions were observed this year or last. Nearly constant overflow from a clear pool occurred. The only variations in overflow occurred following some eruptions of Fan and Mortar Geysers. Spiteful's pool level then occasionally dropped to below overflow, taking about an hour to recover following the end of Fan and Mortar's eruption. These drops in Spiteful's pool level amounted to 6 - 12 inches. Constant bubbling occurred at the upstream end of the pool. Water sizzled from several locations in the gravel near the upstream (northeast) end of the pool.

Spiteful erupted frequently during the late 1960's to heights of 10 - 12 feet for 2 - 3 minutes, and intervals of 15 - 17 minutes (Marler, pg. 84). The geyser appeared to be entering dormancy in 1970.

SQUARE SPRING

The spring produced periodic overflow throughout the summer. Just enough algae grew to give the spring a slight greenish color. The spring's level rose in October. The periodic overflow then reached almost into Culvert Geyser's pool. The amplitude of pool level fluctuations at this time was 3 - 4 inches. The pool's level rose slowly over several minutes, then remained "up" for about two minutes, and dropped quickly afterwards. Upper pool levels were accompanied by surface waves (ripples) which radiated from the spring's center. A calm pool was present at low pool levels. Intervals between upper pool levels were 5 - 6 minutes. Square Spring's pool level fluctuations showed a definite relationship with Culvert and Persistent Geysers. The pool level of all three features rose and fell with a fairly consistent pattern (page 297). Culvert Geyser was not effected by Giant's eruption on September 12 (Stephens, pg. 6), thus Culvert and Square Spring are probably not connected with Giant Geyser. Possible eruptions may have occurred on rare occasions in the past, though none were observed (Marler, pg. 94).

BONITA POOL

The pool's activity always related to activity by Daisy Geyser. Water was visible in the pool about 30 minutes prior to Daisy's eruptions. At this time Bonita's pool level would be about six inches below its high-water mark, or about 10 inches or more below overflow. Occasional 2 - 4 inch bubbling was also noted at this time. bubbling in the pool was always visible about 20 minutes before Daisy's eruptions. A small vent about one foot north of Bonita's main pool would begin bubbling 3 - 5 inches in height about 10 minutes prior to Daisy's eruption. This "north vent" of Bonita's Pool was a reliable indicator that Daisy's eruption was soon to come. At this time Bonita's main pool was still bubbling lightly.

About two minutes into Daisy's eruption, Bonita's north vent would be erupting steadily to 6 - 10 inches high, and the main pool was empty. Just visible bubbling in the north vent was common about four minutes after Daisy's eruption ended. Bonita was empty and completely quiet about eight minutes after Daisy's eruption ended. The pool and north vent then remained quiet and empty until water was again visible in the main pool about 30 minutes (maybe more) prior to Daisy's next eruption.

Bonita had usually been in overflow from the 1930's through the 1960's (Marler, pg. 173). This overflow produced highly irregular intervals in Daisy's eruptions. Bonita's overflow fluctuated on and off during 1967 and 1968. At this time Daisy would try to overflow and erupt. The present activity could be a continued trend away from Bonita's previous constant overflow to the present no overflow condition. Marler mentions building up Bonita's pool rim on several occasions to prevent overflow. No mention is made to whether the pool's rim remains "secretly" built up today, thus promoting Daisy's eruptions. Was the surrounding ground returned to its original level following the removal of the parking lot which existed in the area?

BRILLIANT POOL

This pool's activity followed eruptions of Daisy Geyser. The pool was full nearly to rim top about 10 minutes prior to Daisy's eruptions. The pool was clear and mildly bubbling at this time. The pool's level began dropping almost immediately upon the initiation of Daisy's eruptions. The pool's level was about one foot below rim top two minutes into Daisy's eruptions. The pool was still at this point 5 - 10 minutes after Daisy's eruptions ended. The pool's level was back up to about 2 - 4 inches below rim top 20 minutes prior to Daisy's eruptions. Mild bubbling was also observed at this time. The pool's level continued to rise to near rim top and the bubbling continued, up until Daisy's next eruption began. The pool's upper levels may have included light overflow.

The pool's present fluctuations in response to Daisy's eruptions remains fairly consistent with past observations (Marler, pg. 176). Periods of overflow occurred in the 1950's, all of which delayed Daisy's eruptions. Brilliant's pool drops more with eruptions of Splendid than Daisy. 20 - 30 foot eruptions of Brilliant Pool have been observed following 3 - 4 successive eruptions of Splendid.

COMET GEYSER

The geyser produced cyclical periods of play about 20 minutes prior to Daisy's eruptions. This activity amounted to constant bursting which splashed water all around the geyser's cone. This activity no doubt is why the cone is as big as it is. At this time play reached 3 - 5 feet for about one minute followed by lesser play (0 - 2 feet) during the next minute, then back to one minute of stronger play. This activity continued up until Daisy's eruption. Sometimes play tended to increase as Daisy's eruption neared. The strength and duration of play usually increased slightly during the first two minutes of Daisy's eruption, followed by lesser play. Occasional play then resumed within 10 minutes after Daisy's eruption ended. Sometimes Comet had continuous boiling about one foot high during Daisy's eruption, and after the eruption the play would pick up to 1 - 2 feet high. Comet's activity was always changing such that a definite pattern to its activity and that of Daisy was not readily apparent.

Comet's present activity is much like the past with periods of wet bursting/splashing (Marler, pg. 178). The geyser was originally named "Spray Geyser" in 1878 and "Comet Geyser" was the present-day Daisy Geyser.

DAISY GEYSER

The geyser was quiet and in possible light overflow 25 - 40 minutes prior to an eruption. Bubbling in the main pool began about 18 - 20 minutes before an eruption. Occasional or at times constant splashing was present about 10 minutes prior to an eruption. At this time play was from several locations in Daisy's pool as well as from a "west vent" just west and above the main pool. Constant mild bursting about one foot high from the main vent and the west vent occurred about five minutes prior to an eruption as well as occasional one foot main vent domed bursts. The bursting and splashing reached 1 - 3 feet in height about 10 - 15 seconds prior to an eruption. The west and main vent activity then elevated to 3 - 5 feet for about five seconds, after which the main vent's eruption grew steadily to 60 - 75 feet. Eruptions were angled slightly to the north. This height was maintained for about three minutes. The eruption's height gradually dropped off during the last minute of the eruption. The west vent's play usually lasted about 10 seconds longer than the main pool's play. The steady liquid output finally ceased, and was usually followed by 1 - 3 two foot bursts. I noted the end of these bursts as the end of an eruption. Daisy produced an occasional gurgle about 10 minutes after an eruption ended. Trickling overflow was then the first activity prior to the next eruption.

Daisy's average eruption duration was 3m 34s, and average eruption interval was 86m (Fig. 1 & 2, pg. 307). The longer intervals in Figure 2 relate to around the time of Splendid's eruption on May 29. Daisy's intervals usually increased on windy days by as much as 10 minutes above the average, with a five minute increase not uncommon. The geyser's average interval vs. time of day is graphed on page 308). Note here the trend toward slightly

shorter intervals during the daylight hours. This is the same diurnal pattern noted in Plume Geyser last year (Landis, pg. 49). Daisy's exhibiting a diurnal pattern did not surprise me since the geyser also shows a strong correlation to wind affects. This shows that diurnal trends occur in geysers other than those on Geyser Hill. The extreme data points on Daisy's diurnal graph represent the Upper Basin's common mid-day wind's, shorter no-wind mid-day intervals, and the fact that all intervals were observed during the day (data was not averaged as it was at night).

I believe Marler may be partially correct in that Daisy's wind effects are due to an increased rate of discharge (Marler, pg. 184). Note here that Bonita Pool did not overflow this summer and Brilliant Pool's overflow was cyclical and slight, if any. But also note that the wind does not always blow in a direction which increases the rate of discharge (wind from the south). Also note that Daisy is connected to Splendid, Comet, Brilliant, and Bonita. Heat loss from all these pools together combines to effect Daisy's intervals. Last year I calculated that a 15 mph (6.7 mps) wind increases the heat transfer from a non-boiling pool at 97°C by 25% (Landis, Figure 22). Wind definitely has an effect on pool surface heat transfer. The question pertaining to each geyser is: Do the geyser and its related features have enough pool surface area and small enough water volume so that a given wind speed removes enough heat from the pool(s) to significantly alter the equilibrium of the subsurface water-storage areas. In Daisy's case the answer is yes.

Daisy was definitely affected by the August 24 earthquake (page 309). Note the intervals began to shorten one interval prior to the earthquake. This shift in a geyser's interval prior to an earthquake has been noted in Old Faithful as well (Rick Hutchinson). It is possible the geysers may sense the increased stress in the earth's crust in that water and heat may flow more easily as the earth's crust begins to fracture just prior to an earthquake. Daisy's overall average daily interval for the summer is shown on page 310. The effects of the August 24 earthquake are apparent here with "short" intervals continuing for about one week after the earthquake. Also note the weekly average interval for part of 1987 was about 10% shorter than this year's average. Possible long-term oscillations in Daisy's interval could imply a shifting of energy to other geysers (maybe Giant?).

Daisy's present average interval is about the same as at the turn of the century (Marler, pg. 184). Between 1930 and 1960 intervals increased to the 110 - 140 minute range, along with overflow by Brilliant and Bonita Pools. Past and present observations show how unstable the equilibrium is in Daisy Geyser and other nearby features.

DAISY'S THIEF GEYSER

No above-ground activity was observed this summer. No water was expelled from the vent during any part of Daisy's eruptive cycle. A small nearby spring resembling a semi-recent blowout produced visible (2 - 3 inch) bubbling in accordance to Daisy's eruptive cycle. This vent is labeled "Blowout" on the map of the Daisy area on page 339.

Daisy's Thief was first observed in 1942 (Marler, pg. 190). Eruptions of the Thief reached heights of 10 - 15 feet and delayed Daisy's eruptions. Daisy's Thief was last seen by Marler in 1968.

PYRAMID GEYSER

The geyser was active this summer. On several occasions I observed it in eruption when viewed from Daisy Geyser. The White Pyramid Throne which towers above Pyramid Geyser is possibly the original vent, prior to Pyramid's existence. The "throne" still emits steam, visible even on warm days.

SPLENDID GEYSER

One eruption was observed this year on May 29. This eruption occurred about 10 minutes after Daisy erupted. On July 2 and August 5, Splendid was once each day observed producing 10 - 30 fast climbing bursts which lasted about five seconds. Both of these bursts occurred about 10 minutes after an eruption of Daisy Geyser. Though I have never seen an eruption of Splendid, it was obvious that Splendid was "bursting" in what might be considered a minor eruption. The burst was vertical rather than angled like Daisy's is, and was coming from an area much closer to the trees west of the geyser group. A knowledgeable visitor confirmed the origin of the activity I observed.

The geyser's only other activity was occasional individual and overlapping 1 - 2 foot splashes and slight overflow (more than a trickle). The geyser was quiet and calm for about two minutes following eruptions of Daisy Geyser. Splendid has had periods of activity in the past most notably in the late 1800's and the early 1950's (Marler, pg. 200). Eruptions reached heights of 150 - 200 feet and lasted 2 - 20 minutes.

ARTEMISIA GEYSER

Eruptions were preceded by several hours of continuous overflow. The amount of overflow fluctuated in accordance to 1 - 2 inch fluctuations in the geyser's pool level. Peak to peak cycles of overflow and upper pool level occurred about every 10 - 15 minutes. This cycle time was noted about one hour before an eruption. The pool's overflow surged over the entire rim about 40 seconds before an eruption. Strong thumping was felt at this time while sitting on the old road bed just north of the geyser.

Eruptions were of a boiling form which slowly grew to about five feet in height about 40 seconds into an eruption. Brief periods of a "doming" pool surface without boils occurred during the first two minutes of an eruption. The pool's level dropped 4 - 6 inches prior to some boils, and then rose during the boils. Boils were strongest at two locations along an approximate north-south line within the main vent. Common boil heights were 5 - 15 feet about four minutes into the eruption, with 20 - 25 foot boils on occasion. The eruption's strength continued to be cyclical at this time, though the "northernmost" boils seemed to be stronger than the southern boils. Boils reached about 35 feet 10 minutes into an eruption. The eruption's strength began to drop off about 16 - 18 minutes into an eruption. Boils reached 2 - 5 feet in height about 18 - 20 minutes into an eruption. Momentary pauses in all activity began occurring at this time. A long pause finally signaled the end of an eruption. The pool's level was about two feet below rim top one minute after an eruption ended. Slight bubbling occurred at this time. The average eruption duration was 19m 49s (Fig. 1, pg. 311). The geyser's pool slowly refilled to overflow over several hours time. Last year I noted that first overflow occurred about 4 1/2 hours after an eruption (Landis, pg. 70).

Lynn Stephens contributed much of the data graphed on page 311. She noted several minor eruptions occurred, with durations lasting only about

5 - 6 minutes. An overall average eruption duration of 18m 13s was then computed. One minor eruption was observed two hours after a major (Fig. 2, pg. 311). The average eruption interval was 9h 50m, with ranges from 8 - 12 hours observed. Note the "shorter" overall average interval of 9h 3m when minors were included. It would be easy for observers to record 8 - 9 hour intervals not knowing the minors had occurred while they were gone from the area.

The earliest detailed references to the geyser's activity are prior to 1929, when 20 - 25 minute eruptions reached heights of 15 - 35 feet (Marler, pg. 40). Detailed observations in 1970 listed much the same activity as early references. The present activity is much the same as in the past, except that minor eruptions were observed this year. These minors may be of the same form that was noted prior to 1929 when 10 - 15 foot eruptions lasted a few minutes at most. Artemisia was first observed erupting in 1886, and was named for its sage-colored deposits (Whittlesey, pg. 15).

ATOMIZER GEYSER

The geyser's vent filled with water within five minutes of an eruption. The geyser's pool was overflowing its rim along with constant bubbling about one minute prior to erupting. Major eruptions began quickly; reaching over 30 feet soon after an eruption began. The eruption's strength fluctuated throughout an eruption, though overlapping bursts of spray usually occurred. Eruptive heights varied from 3 - 10 feet, to 25 - 30 and 35 - 40 feet at various times. The "old cone" just north of the main cone produced light steam puffs and possible light spray during the "south cone's" eruptions. The liquid portion of an eruption came and went about nine minutes into an eruption, with strong steam play beginning (on and off) at this time. Liquid phases of Atomizer's major eruptions lasted about 9 - 12 minutes. Forced steam output continued for another 9 - 10 minutes. The true end of the steam phases was difficult to note, since the steam output gradually decreased to slightly force, rolling steam. Following the end of continuous steam output (end of eruption), cyclical periods of steam output continued for at least another 40 minutes.

Major eruption durations averaged 30 minutes (Fig. 1, pg 312). Minor eruption durations averaged 50 seconds. Lynn Stephens and possibly other observers contributed most of the data which disclosed the geyser's eruptive cycle. A series of minor eruptions occurred which led up to a major eruption. According to Lynn, the first minor occurred about nine hours after a major eruption. Durations of these minor eruptions were about 20 - 40 seconds. Intervals between minors averaged about 1 - 2 hours (page 313). Durations of minor eruptions continued to increase as a major eruption neared, with minor durations of about 70 - 80 seconds occurring just prior to a major eruption (Fig. 1, pages 312 & 313). Intervals between eruptions within a series of minors averaged 80 minutes (Fig. 2, pg. 312), and tended to shorten 1 - 2 intervals prior to a major eruption (Fig. 2, pg 313). Major eruptions occurred 60 - 80 minutes after a minor eruption (Fig. 2, pg 313).

Intervals between major eruptions averaged 15h 50m (fig. 3, pg 312); thus about 5 - 6 hours of the interval between major eruptions included minor eruptions. Last year I observed minor eruptions lasting under one minute and reaching heights of about 10 feet.

Atomizer was named in 1885 - 1888 for the way its eruptions break up into a fine spray (Whittlesey, pg. 18). The occurrence of several minor eruptions between major eruptions was noted after 1959; though probably because these were the first dedicated observations of the geyser (Marler, pg. 45). Activity describing present day minor and major eruption durations was noted in 1935.

The "north cone" presently emits steam and occasionally some liquid during major eruptions of the "south cone," thus a connection between the two cones is very apparent. The "sealed off" north cone was found broken open in mid--summer of last year (1987). Close inspection by myself and others led us to believe vandalism was the most likely cause of the cone's radical change in appearance.

FANTAIL GEYSER

Several eruptions occurred over the summer. One eruption in mid-August was observed reaching a height of about 50 feet, and having a duration of about three minutes (Rocco Paperiello). Another eruption followed this one in less than 20 hours. Several other possible eruptions occurred during mid-August, as verified by markers and dead grass. Other than this one group of eruptions, markers suggested eruptions occurred about every 30 days or more. I would not rely on visitor reports to suggest the frequency of Fantail's eruptions. Rather, wooden markers on top of small stones worked fairly well as long as wind and rain was kept in mind. Piles of sand were also employed as back-up markers. As a case in point, I talked to an older woman who provided a sincere and detailed description of this year's June 28 eruption of Giant Geyser. She had not reported the eruption and only asked me when it was going to erupt next, as she thought Giant's eruption was very nice and would like to see it again.

Fantail produced cyclical stronger overflow during most of my observations this year. The geyser's pool level rose 1 - 2 inches at intervals of 10 - 15 minutes and remained at these upper levels for 1 - 5 minutes. Stronger boiling occurred at the higher pool levels with occasional 1 - 2 foot boils observed. Overflow continued at lower pool levels and was usually accompanied by superheated bubbling. The geyser's pool was always clear. The fluctuation of the geyser's pool level decreased notably during September and October (approximately).

Fantail has only been active as a geyser since about 1986 (I believe). I am fairly certain the geyser was named by Rick Hutchinson. A detailed study of the geyser's early activity has been written by Rocco Paperiello and Marie Wolf.

OTHER GEYSERS NEAR GREAT FOUNTAIN

Eruption intervals and durations for the following geysers are on pages 314 & 315.

A-2 Geyser: 1/2 - 3 feet, individual spits and domed bursts.

Botryoidal Spring: 1 - 4 feet, rolling boil, some individual large and small bursts.

Crack Geyser: 4 - 6 feet, pulsing constant spray.

Gemini Geyser: 1 - 6 feet, liquid and steam phase, 2 vents.

Logbridge Geyser: I observed one 30s constant spray eruption to 3 - 4 feet in height. A 2 - 3 second steam phase ended the eruption.

Narcissus Geyser: I observed one 10m eruption consisting of 3 - 20 foot individual bursts with 5 - 10 seconds between bursts. The pool drained completely in less than 45 seconds.

White Dome Geyser: 20 - 30+ feet above ground, steady spray, liquid and steam phase.

GREAT FOUNTAIN GEYSER

I observed one eruption of Great Fountain Geyser; a description follows. One hour prior to the eruption the already-in-progress overflow began noticeably spilling over a main sinter ledge about 20 yards east of the cone. All shelves around the geyser had water in them at this time and runoff was trickle-flowing to all runoff channels. The first boils in the geyser's main pool occurred 40 minutes before the eruption. Boiling increased substantially about 30 minutes before the eruption, now reaching 1 - 2 feet in height. Periods to the strong boiling began to develop. Boils were reaching 3 - 8 feet in height and lasting over 20 seconds about 10 minutes before the eruption. Periods of a calm pool were about one minute apart at this time. The last quiet period occurred one minute before the eruption, and was followed by a constant, slowly climbing water column.

I noted the start of the eruption when the height suddenly jumped to over 10 feet. Initial eruptive activity included a 4 - 15 foot constant rolling boil for 40 seconds. Ten seconds of calm followed this boiling. Ten seconds later the water column rose to five feet in height for another 10 seconds; then suddenly shot to 60 - 75 feet or more. Five seconds after this the pool was quiet. Individual 25 - 40 foot bursts and boils followed. Many bursts began with a strong thump; thus there occurred "thumpbursts." The eruption was issuing from an out-of-view pool one minute into the eruption.

Four minutes into the eruption activity included individual and overlapping bursts, full vent bursts, domed bursts, tall column "spits," bursts flying left to right and vice versa. Activity reached 10 - 50 feet at this time with occasional 100 footers (or more). Pauses in activity became more numerous during the last two minutes of the eruption's first burst. Pauses were separated by 40-100 foot (or more) bursts. The geyser's pool level was out of view following the end of the eruption's first burst. Thrashing and boiling began about one minute before the second burst. The second eruption was

noted as having a 40 foot full-vent domed burst. Several periods of thrashing and boiling followed by calm occurred between the second and third bursts. The third burst had a single burst to over 100 feet, a 30 - 70 foot constant eruption for 12 seconds, and a burst reaching over 150 feet (in order). During the pause between the third and fourth bursts I could easily see the water column from Fountain Geyser's eruption. Great Fountain's fourth burst included 10-20 footers, 30-60 footers, and one burst over 75 feet. The fifth burst included 10-40 foot bursts. White Dome erupted one minute before the end of Great Fountain's fifth burst. Periods of 2 - 4 foot boiling the end of the eruption. 16 minutes after the eruption individual spits shot to 10-15 feet. Occasional periods of strong rumbling now occurred with no visible water. The small geyser about 50- 75 yards west of Great Fountain began clearly audible chugging 26 minutes after the eruption ended. Heavy runoff was still leaving the outer terraces surrounding the pool at this time.

Page 316 shows the duration of each burst and the pauses between bursts as a function of when they began in the eruption. Many Great Fountain "Super Bursts" over 200 feet high were observed this summer. Eruption intervals this summer averaged about 10 -12 hours.

ANGLE GEYSER AREA

The Angle Group consists of four geysers. There are also two vents which serve as drains for two of the geysers. See the map on page 341 for the location of each feature. The activity of the group's four geysers was as follows:

North Angle Geyser's eruption consisted of a constant series of overlapping bursts from 1 - 4 feet in height. Most all the water expelled by an eruption flowed northeast into North Angle's drain pool. This drain pool's water level never rose to overflow; rather its pool level remained about the same even as North Angle's overflow poured into it. The drain's pool was always clear and calm. North Angle's eruptions ended quickly, and the geyser's pool drained quickly afterwards. The geyser's water stood 8 - 10 inches down one minute after an eruption. Eruption durations averaged 4m 26s with an overall average interval of 41m (Fig. 1 & 2, pg. 317). North Angle's intervals were affected by eruptions of South Angle and Northwest Angle (Fig. 2, pg. 318). Note that North Angle's intervals averaged only 25m 16s when Northwest Angle was not active. Northwest Angle's eruptions caused a notable delay in North Angle's intervals, with the latter's intervals averaging 99m following eruptions of Northwest Angle. These long intervals were also promoted by eruptions of South Angle Geyser.

South Angle Geyser's eruptions consisted of a climbing 1 - 3 foot eruption. Eruptions reached full height after several minutes of activity. Eruption durations and intervals averaged 15m 15s and 2h 18m respectively (Fig. 3 & 4, pg. 317). Eruptions of South Angle caused longer intervals to occur between North Angle's eruptions (Fig. 2, pg. 318). Note that South Angle's

eruption at about 1730 (with no northwest angle) increased North Angle's interval by about 50%.

Northwest Angle's eruptions reached 1 - 3 feet in height. Play included constant bursting. Eruptions ended quickly, after which the geyser's pool drained quickly. Overflow produced by eruptions drained into a drain southwest of the geyser. This drain's water level remained constant regardless of the amount of discharge it received. The geyser's water level was about one foot down 50m after an eruption. Eruption durations and intervals averaged 23m and 2h 16m respectively (Fig. 1 & 2, pg. 319). Eruptions of Northwest Angle caused major delays in North Angle's eruptions (Fig. 2, pg. 318). Note that North Angle's intervals increased by over 300% following eruptions of Northwest Angle.

Northeast Angle Geyser played to heights of 1/2 - 1 foot, only when South Angle Geyser played. Northeast Angle's eruptions consisted of intermittent bursting.

The Pool Geyser Group immediately east of the Angle Group produced occasional bursts from several of its vents. See map on page 341. All four of the group's vents are submerged under one common pool. Activity was not timed, and could easily have related to activity in the Angle Group, though no readily apparent relationships were noted. The Pool Group's eruptions consisted of individual small bursts which were not visible from a distance.

Little Angle Geyser's vent is located about four yards south of South Angle Geyser. Eruptions consisted of a slowly climbing eruption, initiating with a 1/2 foot eruption and climbing to about 4 feet in heights. Durations and intervals of eruptions averaged 1m 43s and 53m respectively. (Fig. 3 & 4, pg. 319). An important note is that this geyser's eruptions showed no relationship to activity in the Angle Group, and yet Little Crack Geyser's eruptions were clearly related to the Angle Group. The Angle Group and Crack Group must lie along the same fault, and Little Angle Geyser must lie off to one side of the fault.

Little Crack Geyser's eruptions consisted of steady play from 1 - 10 feet in height. Eruption intervals averaged 21m 33s and durations averaged 46 seconds (Fig. 2, pg 320). Note the multi-modal eruption durations. Now look

at Figure 2, page 318 which compares Little Crack's durations to activity in the Angle Group. Note Little Crack's durations are short when eruptions occur frequently in the Angle Group, and are long when long intervals have occurred in the Angle Group. I assume Little Crack Geyser is connected to the Angle Group via a common underground fault.

BLOWOUT GEYSER

There is apparently some confusion as to when this geyser's vent formed. I was told the vent opened up in 1964, hence the name 1964 Blowout is used in my notes. Marler's inventory lists a "Blowout Spring" on page 535. This spring's vent diameter and location are within 1/2 foot and four feet respective of measurements Jens Day and I took while locating the "1964 Blowout", yet Marler notes the blowout formed the night of August 17, 1959 as a result of the Hebgen Lake earthquake. I'll stick to the earliest reference. The name Blowout Spring will have to be changed to Blowout Geyser following the first-ever-observed eruptions that I observed on June 17, 1988. Eruptions were of a height comparable to those of Honeycomb, Kaleidoscope, and Drain Geysers.

The geyser's pool level remained about 3 - 4 feet below rim top between eruptions. During this time the pool was milky blue with slight bubbling. The pool's color was very similar to the Drain's pool color that day. The Blowout's pool level rose up and down several inches, though not necessarily along with fluctuations in the Drain's pool level. The Blowout's pool level rose to a point about 2 feet below rim top before an eruption. Constant mild bubbling continued at this time. Eruptions jumped from the vent to initial heights of 20 - 25 feet. Eruptions were of a continuous bursting form to varying heights with 10 - 15 feet common, though maximum heights of over 30 feet were noted. Small rocks were occasionally thrown from the vent during an eruption. Runoff from eruptions flowed into Drain Geyser's pool. Eruptions ended as quickly as they started. The geyser's pool level was about 7 - 8 feet below rim top two minutes after an eruption. The pool level was up to 4 feet below rim top 20 minutes after an eruption, and had fully recovered to within 1 1/2 feet of overflow 90 minutes after an eruption (about 2 hours prior to the next eruption). The pool level remained basically at this level until the next eruption. Bubbling was constant from 20 minutes after an eruption until the next eruption.

Eruption durations and intervals averaged 2m 35s and 3h 50m respectively (Fig. 1 & 2, pg. 321). The Blowout's intervals continued to increase as the day progressed (page 322). The Blowout's eruptions occurred on the same day as eruptions of Kaleidoscope Geyser; thus it is possible that the former's interval pattern was in response to the latter's eruptions.

Marler noted that large blocks of sinter lay scattered about following the formation of the vent (Marler, pg. 535). These blocks still remain at present. Some of them were easily one foot thick and over two feet on a side.

DEEP BLUE GEYSER

The geyser's pool continued to live up to its name. Its clear blue color was much like Sapphire Pools' color. Deep Blue's pool was calm between eruptions. The pool level rose 4 - 8 inches prior to an eruption. Eruptions occurred from a pool level at least six inches below a flat shelf which extended south of the geyser. These low pool eruptions were occurring because the continuous eruption of Deep Blue's satellite vent drained water from Deep Blue's pool (Rick Hutchinson).

Slight bubbling and doming of the pool's surface occurred 1 - 2 minutes before an eruption. The surface doming was just enough to stretch the surface so that the ripples caused by the bubbling smoothed out. The pool surface then domed and pulsed about one minute prior to an eruption. Strong thumps produced waves which radiated in all directions. Some eruptions begin shortly after the first thumps while other eruptions occurred after several periods of thumping over about 1 - 1 1/2 minutes' time. There appeared to be three vents at the base of the main pool. Most eruptions occurred from the northeast vent. Large bubbles or a stream of large bubbles could be observed rising from the depths to break the pool's stretched-tight surface. It was great fun to see if you could run fast enough to avoid the splashes from these bursts. Bursts produced 2 - 6 inch or higher waves of overflow which radiated in all directions. Many waves traveled to and fro between bursts; much like a rough sea. These waves were caused by the reflection of the burst-produced waves from the pool's outer rim. Some bursts broke the surface with a commanding "pop". I've referred to these "pops" as bubble bursts when describing similar activity in other geysers.

Most bursts reached 5 - 15 feet in height, while taller ones rose to 25 - 30 feet at most. Occasional super-bursts occurred. I defined these as bursts that filled almost the entire pool, lifting the pool into an immense dome over 20 feet high. These bursts exploded in all directions. The only similar

comparison to this activity was the full-vent bursts produced by Giantess Geyser near the end of its final eruption series, when the main bowl was half-filled with water. In both cases the dome's water had the shape of a baseball cap set on top of the geyser's vent. Most of Deep Blue's bursts were 10 - 20 seconds apart. Sometimes only surface boiling occurred, reaching 2 - 4 feet in height.

On one occasion a 2 - 8 foot constant eruption lasted 49 seconds. Heights of up to 15 feet were noted early in this fountain-type burst. Note that this constant eruption occurred from the southernmost (center) vent of the geyser's three possible vents. Much of the geyser's smaller, brief surface boils also issued from this vent. I never observed eruptive activity from the westernmost vent. It's possible there's no vent there at all, just a dark corner of the main bowl. Eruptions usually ended with surface boiling at the south end of the pool. The pool level dropped 4 - 6 inches following an eruption.

Eruption durations averaged 3m, and intervals averaged 23m 46s (Fig. 1 & 2, pg. 323). I assumed Deep Blue's intervals were affected by the eruptive activity of Deep Blue's satellite vent, since the latter's eruptions lowered Deep Blue's pool level. A definite relationship was noted between Kaleidoscope's Drain and Deep Blue (Fig. 1, pg. 324). Note that the Drain's eruptions increased Deep Blue's intervals by about 33%. Not enough data was collected on October 28 to suggest alterations in Deep Blue's eruptions duration because of the Drain's eruptions. Kaleidoscope Geyser also affected Deep Blue (Fig. 2, pg 322). Note here that Deep Blue's intervals shorten to about the shortest of the day and remain short as long as Kaleidoscope was active. The peaks in Deep Blue's intervals prior to Kaleidoscope's eruption may have been an indicator that Kaleidoscope was approaching an eruption series. Further studies which I intend to do someday may show a direct relationship between Blowout Geyser and Deep Blue. At present only an indirect relationship via Kaleidoscope or Drain Geyser exists.

Several small spouters are located along the west rim of Deep Blue's Pool. Activity by those vents tended to increase in strength prior to Deep Blue's eruptions. This activity and Deep Blue's rise in pool level served as reliable indicators of the time until an eruption. The stretching and smoothing of the

pool's surface along with thumping were the final indicators that the geyser was "ready to blow."

Early references to the Geyser's beautiful pool were noted in 1878 (Marler, pg. 536). No eruptions were observed at this time.

DEEP BLUE'S SATELLITE VENT

When active this geyser produced a 30 - 40 foot constant liquid eruption which was angled slightly to the east. The geyser was active most of the summer.

Eruptions were first observed in February 1988. The geyser erupted continually from February through sometime between July 24 - 26. All activity ceased at this time. The geyser resumed its constant eruption on August 31, seven days after the 2.5R August 24 earthquake which was located very near Lone Star Geyser. The geyser continued to erupt from August 31 through November 16, 1988. There may have been additional brief periods of dormancy between February and November.

The geyser's steady eruptions dropped the pool level in Deep Blue Geyser by about 6 - 12 inches; thus Deep Blue's eruptions occurred from a lower than normal pool level when the satellite vent was active (Rick Hutchinson).

FERRIC GEYSER GROUP

Constant boiling and splashing from 2 - 12 inches high occurred in both the "A" and "B" vents. Both vents were rimmed on two sides by linear mounds of bright orange and yellow algae and/or mineral deposits. Ferric Geyser in Marler's Inventory refers to Ferric "B" Geyser on my map on page 340 (Marler, pg. 551). The present height of splashing is much less than the 2 - 3 feet continuous eruptions observed in the 1950's.

FOUNTAIN GEYSER

Eruptions lasted about an hour with mostly overlapping 20 - 50 foot bursts. John Muller noted on several occasions that Clepsydra ceased its otherwise constant eruption for about 5 - 10 minutes shortly after Fountain's eruptions ended. Lynn Stephens observed a series of intervals ranging from 21h 8m to 14h 58m. A possible sawtooth interval pattern existed with a short interval followed by a long interval, which was then followed by shorter and shorter intervals.

Fountain's eruption on June 17 did not have a definite effect on Deep Blue's intervals (Fig. 2, pg. 322); but note that Deep Blue's interval did have the largest increase in 4 - 5 hours when Fountain erupted. Fountain has exhibited irregular activity ever since the geyser was named in 1871 (Marler, pg. 487). The eruption form has remained very consistent over the years with 10 - 20 feet common and spikes to about 50 feet. No eruptions of Morning Geyser were observed this year.

HONEYCOMB GEYSER

Eruptions were preceded by overflow from the geyser's west pool flowing into the east pool. The west pool exhibited constant bubbling at this time. The east pool's level fluctuated up and down 4 - 6 inches with occasional bubbles. Eruptions began quickly, reaching 5 - 10 feet immediately. Eruptions consisted of numerous individual bursts 10 - 40 seconds apart. Burst durations lasted 4 - 25 seconds with 10 - 20 seconds common. Eruptions occurred from the east pool. Overflow from the east pool submerged both the geyser's vents in one common pool. Activity in Honey's Vent nearly ceased during Honeycomb's eruptions. During one eruption the west vent produced 1 - 4 foot bursts near the end of the east vent's eruption. The average eruption duration was 7m 45s (Fig. 3, pg. 325).

Following an eruption, water from a large area around the geyser poured back into the two vents. The pool levels over the two vents varied slightly 15 - 20 minutes after an eruption so that the west vent's pool ripple-flowed into the east vent's pool. The two pools still appeared as one at this time. Both vents' pool levels were below any overflow 20 - 30 minutes after an eruption. At this time the west pool was 2 - 3 inches below overflow and the east pool was 10 - 12 inches below overflow. The west pool was again flowing into the east pool 40 - 80 minutes after an eruption. Both pools were bubbling mildly at this time. Both pools were again below overflow two hours after an eruption, just as if an eruption had occurred, yet none had. Later on the west pool would resume flowing into the east pool. At times the west pool's runoff poured into the east pool. The west pool usually bubbled. The east pool bubbled at times and was calm at other times. The west pool ceased to overflow into the east pool about every 1 1/2 - 2 1/2 hours.

The west pool was not overflowing into the east pool seven minutes prior to the second eruption I observed. Honeycomb's second eruption occurred

after a 6h 18m interval. This eruption rose to 2 - 10 feet immediately. Heights of over 25 feet were observed two minutes into the eruption. Once again the eruption consisted of individual bursts 20 - 30 seconds apart with burst durations of 10 - 30 seconds.

Honeycomb did not appear to affect Deep Blue's intervals (Fig. 2, pg. 322). Past observations describe eruptions very similar to present activity, except that durations and intervals are currently shorter (Marler, pg. 540).

HONEY'S VENT GEYSER

The geyser's nearly constant activity followed the activity of Honeycomb Geyser. Honey's Vent's pool level dropped to 2 - 3 feet below rim top about 10 minutes after an eruption of Honeycomb. Honeycomb's eruptions reduced Honey's Vent's activity from bursting to constant bubbling. The vent's pool level was 1 - 2 feet below rim top 80 - 90 minutes after Honeycomb's eruptions. At this time Honey's Vent produced 1 - 3 foot bursting which was visible from a distance. The periods of increased bursting lasted 10 - 50 minutes with no consistent pattern, though the intervals between this activity generally decreased as Honeycomb's eruption neared. Bursting reached six feet or more above ground within an hour of Honeycomb's eruptions. The vent's pool level was about 1 - 1 1/2 feet below rim top at this time. Finally Honeycomb would erupt and the Vent's pool level then dropped 2 - 3 feet below rim top. Boiling and bursting reduced to bubbling at this time.

The geyser's activity was never truly periodic enough to establish exact times of eruption terminations. Eruption starts were easy to judge. The present activity never began to approach the 15 - 20 foot minor activity of the past, much less the 35 foot major activity (Marler, pg. 541).

KALEIDOSCOPE GEYSER

Prior to eruptions on the afternoon of June 17, I walked past the "hole in the ground" several times not knowing eruptions could rise from the depths below. No algae growth appeared anywhere near the vent to accent it from the surrounding grey sinter.

Eruptions were the tallest of any geyser in the area that day. One eruption was triangulated at a height of over 45 feet. Light bubbling preceded subsequent eruptions in the 8 eruption series. Eruptions truly rocketed from the vent. Fairly constant height was maintained during an eruption. Eruptions ended as quickly as they started. The pool level dropped to 8 - 10 inches below rim top between eruptions. The last major eruption before a 25m 10s minor eruption was preceded by 13s of 1 - 12 inch bubbling. Evidently this pre-eruption bubbling indicated the eruption series was nearly over.

Eruption durations averaged 38s (Fig. 1, pg. 326), and intervals averaged 3m 57s. Intervals between eruptions occurred in the following order:

4m 25s
3m 11s
12m 16s
2m 15s
2m 06s
2m 03s
1m 12s (minor eruption)
26m 02s (minor eruption)

The first minor eruption involved 1 - 3 foot constant spouting at first. Four minutes into the minor, spouting reached only one foot in height and poured water into Kaleidoscope's Drain. The Drain's pool level did not rise during

this huge influx of water. A 52s pause occurred following the first minor eruption; after which a 2m 40s "smaller minor" occurred. This second minor's constant eruption reached 2 - 20 inches in height. This second minor's activity didn't make it into the graphs. The geyser's pool was four inches below overflow and calm two minutes after the second minor. The pool level was 8 - 10 inches down and calm seven minutes after the minor. 33 minutes after the minor Kaleidoscope's pool was one foot down and still calm. Not a bubble since the end of the second minor. 1 1/2 hours after the minor the pool was still one foot down, but was now producing occasional strong boiling. The Drain's pool level still had not fluctuated since Kaleidoscope's eruptions began.

Kaleidoscope's eruptions shortened Deep Blue's intervals as well as notably dampening the latter's interval fluctuations (Fig. 2, Pg. 322). Blowout Geyser erupted before and after Kaleidoscope's eruption series with steady increases in its intervals. I do not know if the Blowout also erupts on days when Kaleidoscope is quiet and the Drain is active. A small vent a few feet west of Kaleidoscope fluctuated with the latter's pool level at times; at other times the two features didn't readily appear connected.

No relationship between durations and intervals was noted, with 2m 03s intervals and 12m 16s intervals followed by durations within 7% of each other (29s and 31s respectively). This is a change from earlier observations noting a relationship between durations and intervals (Marler, pg. 544). Periods of dormancy still occur, but they seem to be shorter and occur more frequently than in the past where years of dormancy were followed by years of activity. This summer I observed both Kaleidoscope and the Drain active within about four months of each other. I did not perform any observations during this four month time span.

KALEIDOSCOPE'S DRAIN GEYSER

The Drain's pool level rose to within one foot of overflowing to Blowout Geyser's pool about five minutes prior to the Drain's eruptions. The pool level welled up to within inches of overflowing to the Blowout seconds before the Drain erupted. Eruptions were composed of individual bursts lasting 2 - 5 seconds each. Two eruptions were observed. One eruption had one burst and the second eruption had two bursts. A pause of 14 seconds separated the two bursts of the second eruption. Bursts were 10 - 20 feet in height, several feet wide, and had durations of 4 and 20 seconds. The two eruptions were separated by a 1h 28m interval (Fig. 1 & 2, pg. 325).

The geyser's pool level was 8 - 10 inches below overflowing to the blowout five minutes after an eruption. The pool's level dropped slowly after an eruption to a point about two feet below overflow to the Blowout. The pool level then rose quickly within 20 minutes of the next eruption, rising 4 - 6 inches in 10 minutes. Occasional bubbles were noted 10 minutes prior to an eruption, along with occasional pool surface pulsing. Periods of calm and no bubbles separated periods of pulsing. The pool was clear blue the day of the eruptions, rather than the milky blue the day Kaleidoscope was erupting (and not the Drain). The Drain's pool rose an estimated 7 inches in 6 minutes, five minutes prior to the second observed eruption. Bubbles were breaking the surface at this time, and the pool level was about one foot from overflowing to the Blowout.

The Drain's eruptions caused a 33% increase in Deep Blue's interval length (fig. 1, pg. 324). An increase in Deep Blue's eruption duration was caused by these increases in interval length. Blowout Geyser's pool was murky and calm during the time spent observing the Drain's eruptions. Slight (2 - 3 inch) fluctuations in the Blowout's pool level occurred, but the pool never rose to the level at which eruptions occurred earlier in the summer. The

Blowout's murky pool did not imply it was dormant during activity by Drain Geyser, since the Blowout's pool was also murky between its eruptions.

Eruptions of Kaleidoscope's Drain were observed as early as 1946 (Marler, pg. 539). Eruptions have only been observed when Kaleidoscope was dormant.

SPRINKLER GEYSER

The geyser's pool level remained clear, calm, and about two feet below rim top between eruptions. Occasional bubbles were observed 5 - 60 seconds prior to an eruption. The pool level rose from 2 feet down to rim top about 2 - 4 seconds prior to an eruption. Eruptions began immediately upon the pool level reaching ground level. Steady, continuous liquid-bursting form 1 - 3 feet high characterized an eruption. The pool's level quickly dropped following an eruption. Eruption durations and intervals averaged 10s and 2m 30s respectively (Fig 1 & 2, pg. 327). The variations in the geyser's interval length suggests relationships with other nearby thermal features, though no obvious connections were noted. The geyser's vent was surrounded by rich ferric-colored deposits.

Present activity is a notable decrease from the 15 foot high 90 second eruptions of the past (Marler, pg. 555). Present intervals are much shorter than the 20 - 30 minutes that occurred prior to 1970.

UNNAMED POOLS SOUTH OF BLOWOUT GEYSER

Two separate pools lie 68 and 105 feet approximately south of Blowout Geyser. The pool nearest the Blowout (north pool) consists of two pools connected along an east-west line. Both pools (north and south) have large algae-filled runoff channels west of the pools.

The southern pool was observed erupting 1 - 3 feet high during the last 25 minutes of Kaleidoscope's two minor eruptions. Overflow occurred to the pool's western runoff at this time. One eruption duration of 5m 50s was noted; otherwise much semi-continuous bursting to 1 - 2 feet was noted. The north pool's level always dropped to 2 - 3 feet below overflow during the south pool's bursting. Bubbling was observed in the north pool at this time. The south pool's level dropped about 1 foot following its eruptions. The north pool's level would rise to within 2 feet of rim top as the south pool's level dropped.

The south pool was erupting 1 - 2 feet high and overflowing five minutes after Kaleidoscope's second minor eruption ended. The north pool was 2 feet below rim top and bubbling at this time. The south pool's level dropped 1/2 foot below overflow and only bubbled 30 minutes after Kaleidoscope's second minor eruption ended. At this time the north pool's level rose to within 1/2 foot of overflow and began having one foot eruptions from the westernmost of the two connected pools. All runoff from the one foot eruption flowed into the easternmost pool. Ten minutes later the north pool's westernmost pool began having major eruptions 6 - 8 feet high with durations of 12 - 24 seconds. Once again all runoff flowed into the easternmost pool. I never observed runoff from the north pool flowing to its western runoff channel. Intervals varied from 2 - 19 minutes with a 7m average interval. A 4 - 6 inch drop in the westernmost pool's level followed an eruption, after which the pool's level quickly recovered for the next eruption. Eruption intervals had a sawtooth pattern in which a very short

interval (2 - 3 minutes) was followed by a very long interval (10 - 12 minutes; 19 minutes once), after which the intervals shortened back to 2 - 3 minutes in one or two intervals. This activity continued for about 70m, or 100m after the end of Kaleidoscope's second minor eruption. During this time the south pool was in constant overflow.

Around 100 minutes after the end of Kaleidoscope's second minor eruption, the north pool had two long intervals (8 & 10 minutes), followed by two short intervals (3 & 4 minutes), and then three long intervals (11, 7, & 12 minutes). The last long interval was the longest recorded that day. This interval encompassed an eruption of Blowout Geyser.

In summary it is very possible that the two pools' activities are related to the activity in Kaleidoscope Geyser and Blowout Geyser. The observations described above imply that the two pools are closely or loosely connected to the following geysers: Blowout, Kaleidoscope, Drain, Deep Blue, and Deep Blue's Satellite Vent.

ECHINUS GEYSER

One "super" eruption (long duration) and one "minor" eruption (very short duration) were observed. Periods of stronger boiling and constant overflow preceded the super eruption. The super eruption was composed of a series of overlapping and/or individual bursts separated by elevated boiling. Stronger lateral bursts reached the boardwalk north of the geyser, including the stairsteps. The eruption had a boiling form with random vertical and lateral bursts similar to South Purple Pool's eruptions last year. Bursts reached at least 20 feet laterally. Burst heights were 15 - 20 feet commonly with 40 - 60 foot bursts at times. The strongest overflow occurred 30 - 60 seconds into the eruption, and then continued about 10 - 15 minutes into the eruption. Overflow after that was less than half the maximum rate, and was about 1/4 maximum during the last 5 - 10 minutes of the eruption. The duration of the super eruption was 56 minutes. Following the super, the water drained with a whirling pool. The water drained out of view 1m 38s after the eruption ended. Periods of boiling and a rising pool level preceded the minor eruption. The pool did not overflow prior to the minor. The minor eruption lasted 2m 36s. Eruptive heights were 10 - 20 feet with 40 - 50 feet at most. Little or no overflow occurred during the minor eruption. The water in the vent drained from view 1m 12s after the minor eruption ended.

BASIN NORTHWEST OF NORRIS BASIN

The locations of the features described below are shown on the map on page 343. the area was visited by myself and others on July 22, 1988. Numerous thermal observers contributed the information which is compiled below.

Dead Geyser

This inactive geyser had two vents, and is located about 100 yards south of the two explosion craters. The geyser was active in the 1970's. In 1986 the geyser expelled forced steam from the main vent. Water sputtered out of the small second vent located a few feet downhill from the main vent. At present the small vent is almost completely filled in. The main vent is filled in to within 2 feet of ground level. No steam rises from either vent.

The geyser was active at least 10 years before either explosion crater existed. The geyser's energy may have shifted; thus producing the two explosion craters. The large amount of energy continually released by the one explosion crater may mean the geyser will never reactivate.

1986 Explosion Crater

The crater is presently filled in such that the crater's current depth is about 15 feet. The vertical walls of the crater are collapsing into the vent. The original ground level next to the crater is buried under 1 - 4 feet of earth which was thrown out by the explosion or subsequent activity. All trees within 5 yards of the crater are dead. No steam is emitted. The crater was about 25 feet deep when it was active.

1987 Explosion Crater

This currently active vent is located about 40 yards west-northwest and directly downhill of the 1986 crater. The dead geyser and the two explosion craters form a right triangle with the 1987 crater located at the right angle of the triangle. A small depression is located between the two explosion

craters. Constant 1 - 6 foot wet splashes are expelled from the constantly agitated pool. The pool is grey in color and its consistency is thinner than in 1987. Many dead trees bounce about in the churning pool. A mud rim exists 2 - 3 feet above the pool's present level, as if a recent drop in pool level has occurred. This year's tree growth has no mud on it; otherwise, mud covers vegetation 20 or more yards east of the pool. The blast that formed the crater was directed to the east-northeast or a little north of a line drawn between the two craters. All trees in this direction are knocked down for 15 - 20 yards from the center of the crater. Trees west of the crater are caked with 2 - 4 inches of mud up to 15 feet above ground level. The west rim of the crater lies immediately next to a small stream. The blowout's pool level is about 1 - 2 feet above the stream's level.

Thumper Mudpot

The mudpot's vent is 3 x 3 1/2 feet and faces east-southeast. The vent has an amphitheater shape which projects the deep hollow-sounding thumps to great distance. Thumping was heard at least one mile away on the Howard Eaton Trail. The thumping was at first thought to originate from the explosion craters. The mud pot's clay was very thick. Large pieces of clay domed and folded over as air bubbles burst through the surface. Mud was thrown at least 6 feet from the vent. A sulphur-yellow superheated boiling pool lies about 15 feet east-southeast of and directly in line with the mudpot's vent.

Several beautiful sulphur lakes, old inactive geysers and mudpots, and a large sulphur deposit are located north, northeast, and northwest respectively of the explosion craters.

MONUMENT GEYSER BASIN

The area contains 9 major towers in all (2 - 9 feet in height). There are eight features that are non-eroded and still standing. Most of the monuments sealed themselves off. A few features have polished vents.

One active monument stands second from the southern end of the string of features. This tower is about 8 - 9 feet tall with steps of decreasing diameter, as if several active phases occurred, each less intense than before. The active monument produced constant bubbling, almost a wet boil. The outside of the cone was damp 5 or 6 feet up. None of the cones looked damaged by tourists -- yet.

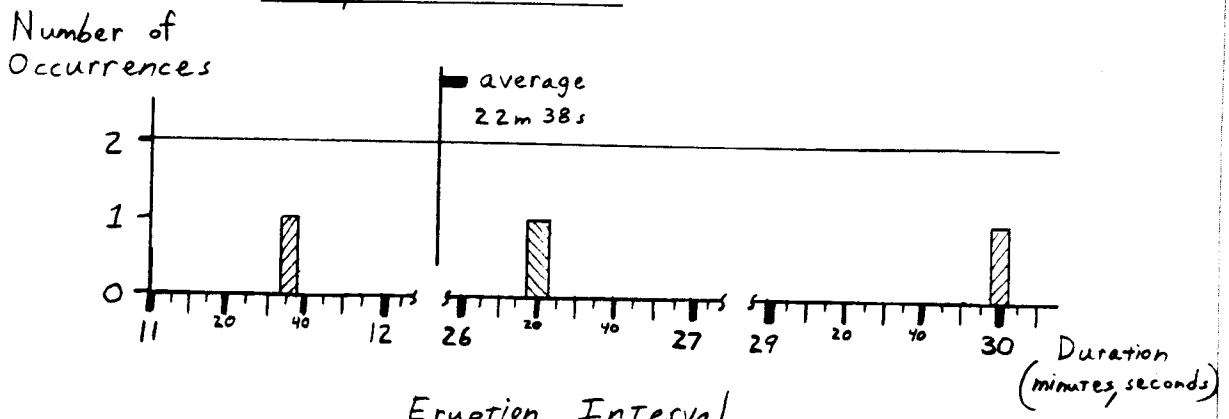
The flatter ground east of the monuments has a saddle shape. Numerous active vents lay on each side of and at the crest of the saddle. Many of these vents produce a frying pan sizzle. One true fumerole exists. One sulphur-yellow pool lies toward the south end of most of the activity. The water in this pool was not as thick as a mud pot, but was thicker than plain water. The pool's surface was broken by constant bubbling and the stained pool rim suggested possible 2 - 3 foot splashes were wetting the rim area at times.

I hate to say it, but the Park Service should obliterate the trail to this special area and let it continue its quiet existence undisturbed.

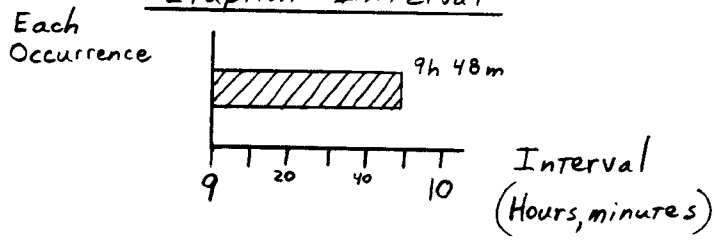
Black Hole Geyser

July 3 and October 1, 1988

Eruption Duration



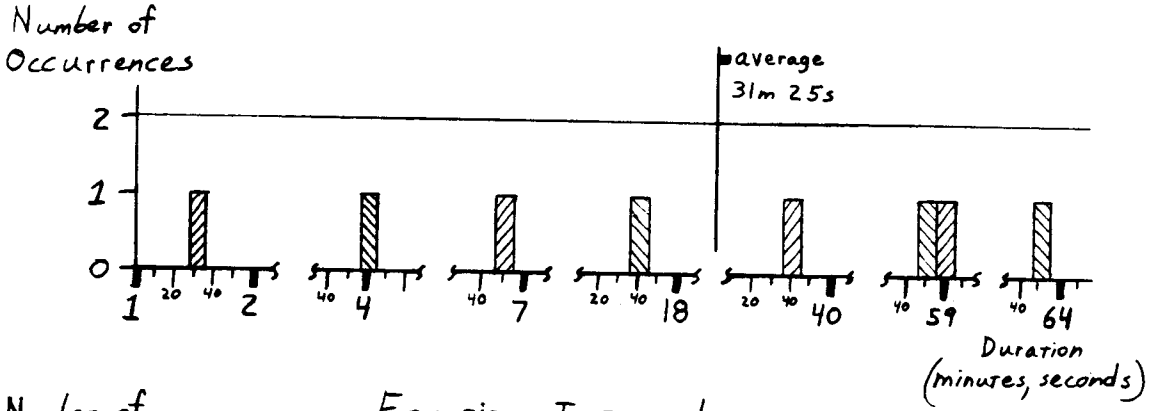
Eruption Interval



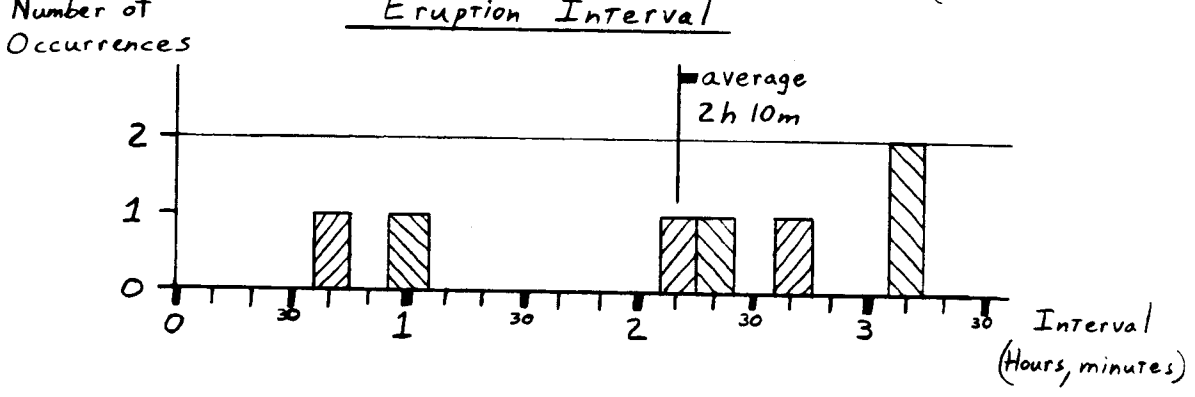
Perforated Cone Geyser

July 3 and October 1, 1988

Eruption Duration



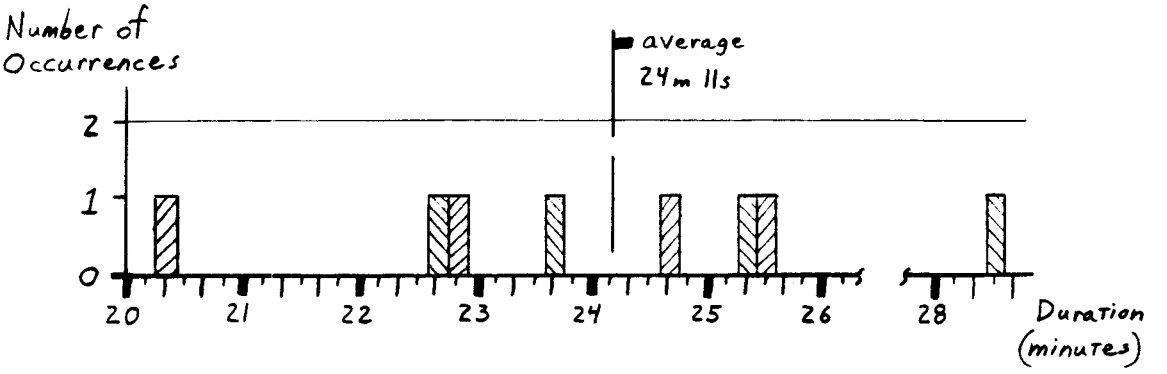
Eruption Interval



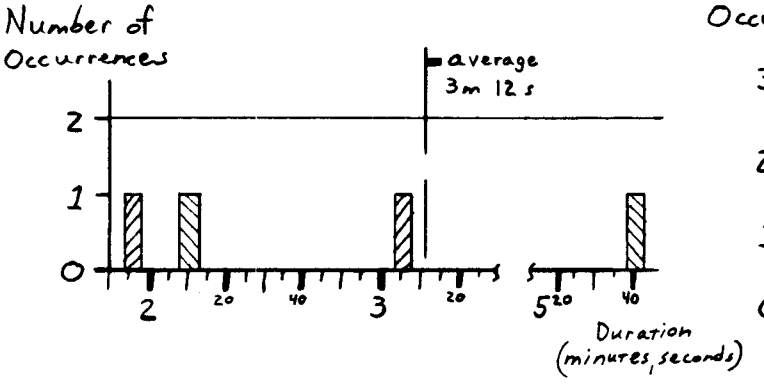
Lone Star Geyser

July 2 and October 1, 1988

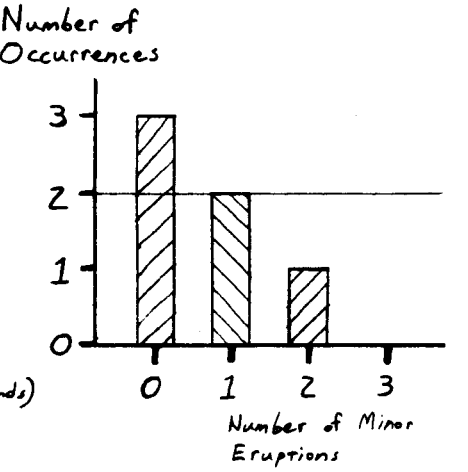
Eruption Duration



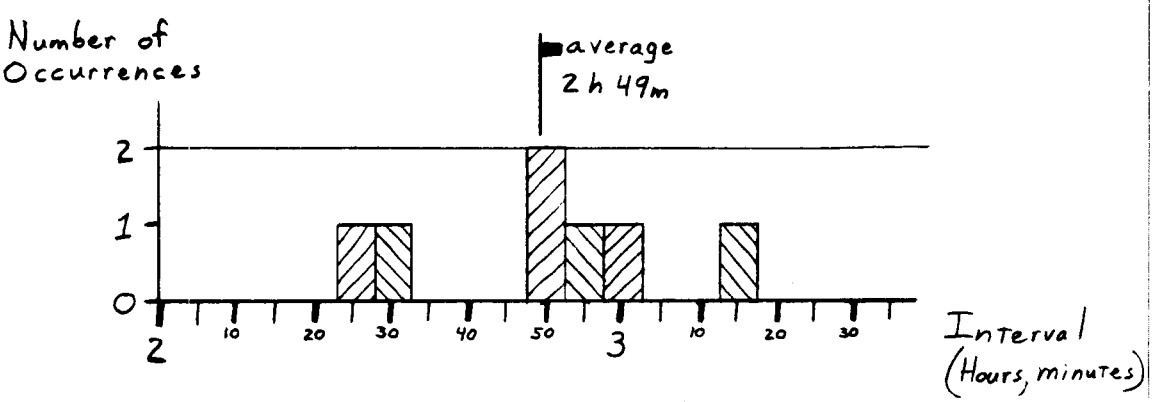
Minor Eruption Duration



Number of Minor Eruptions Between Major Eruptions



Eruption Interval



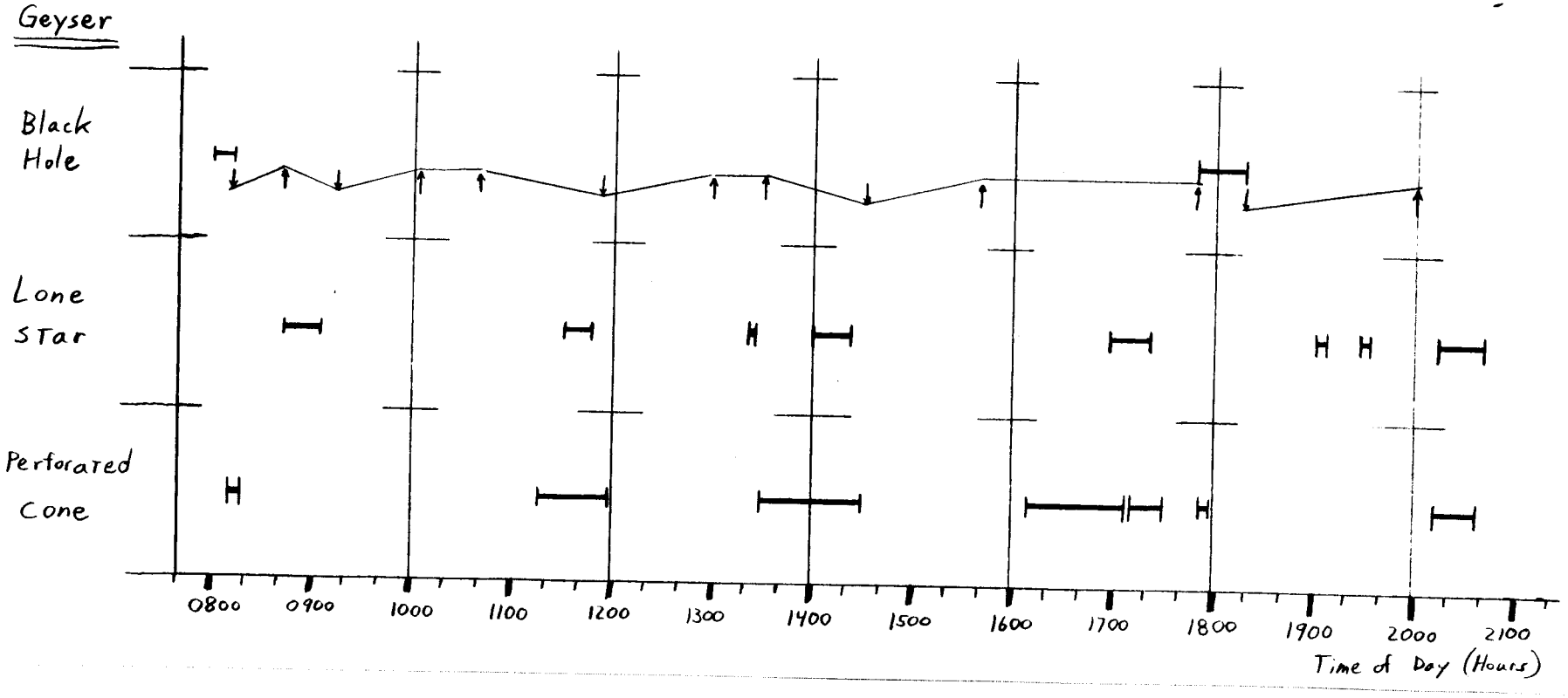
Lone Star Group

July 3, 1988

H ≡ duration of eruption

↑↓ ≡ dropping pool level

↓↑ ≡ rising pool level



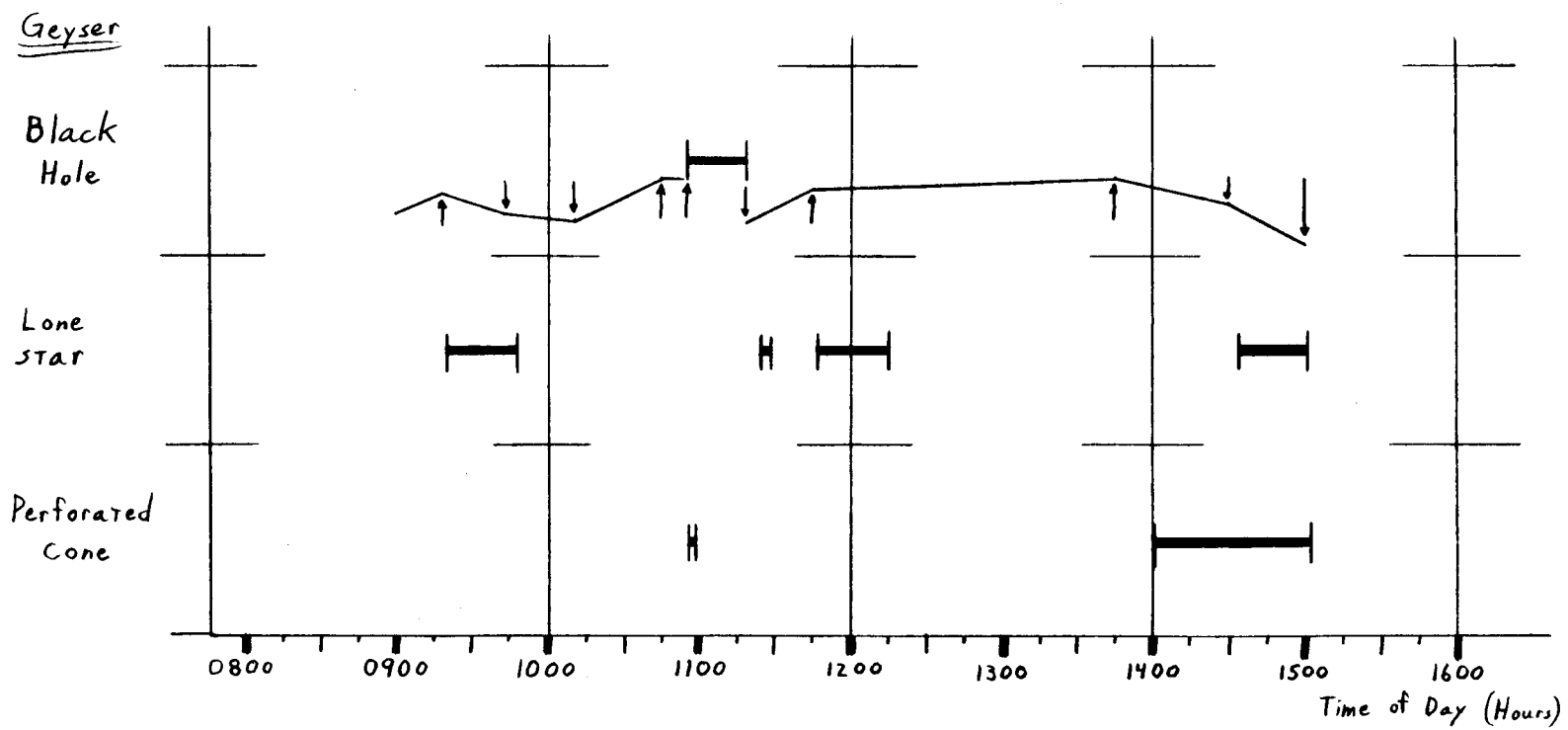
Lone Star Group

October 1, 1988

= Duration of eruption

= Dropping pool level

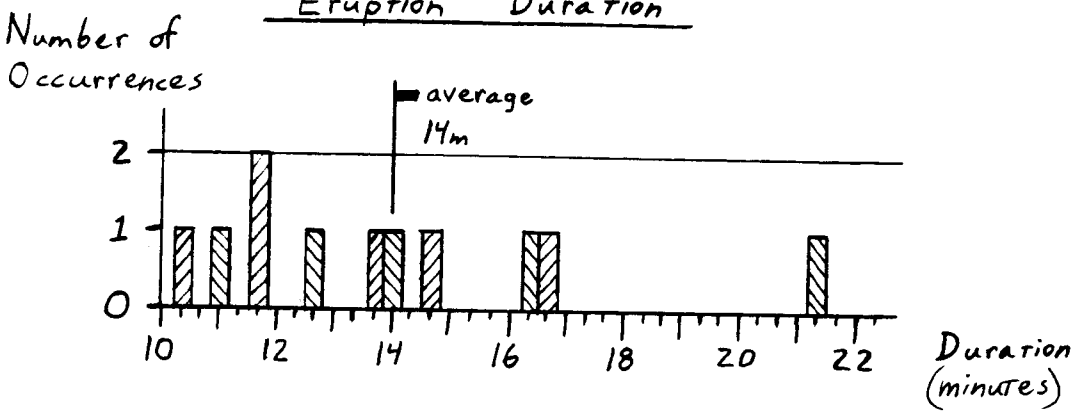
= Rising pool level



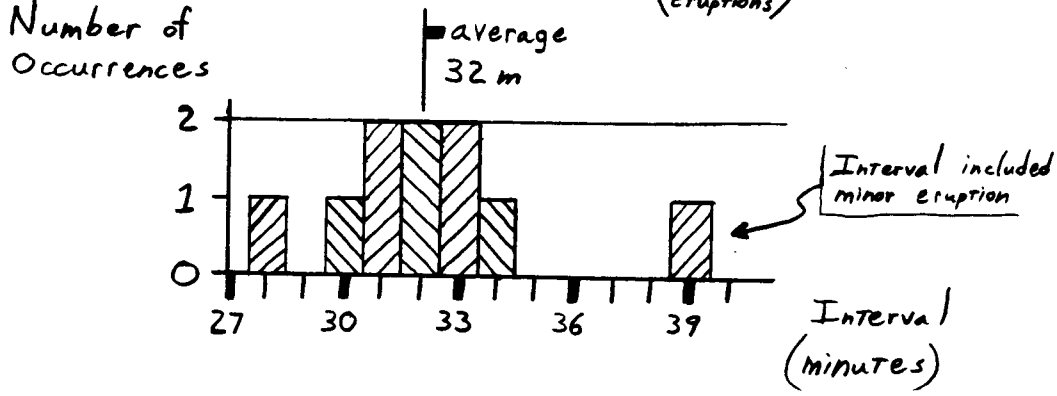
Cliff Geyser

May, 1988

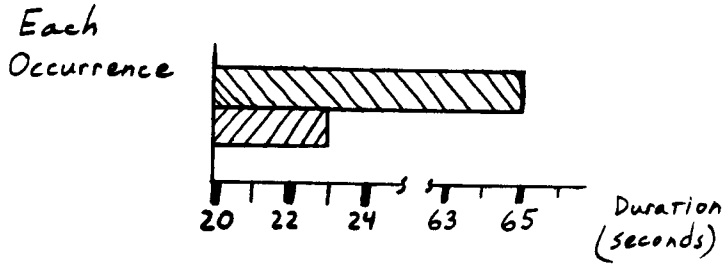
Eruption Duration



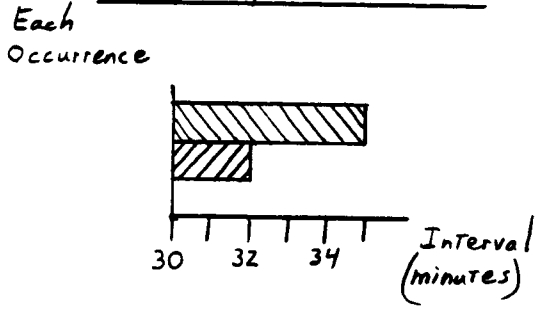
Eruption Interval (Between Major Eruptions)



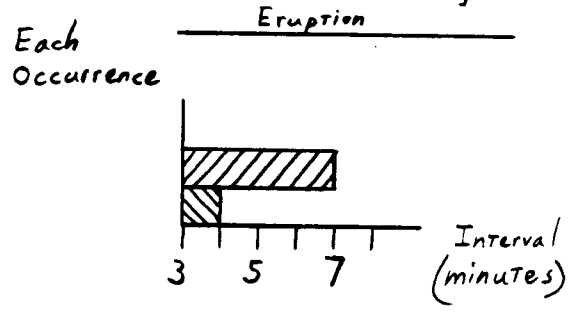
Duration of Minor Eruptions



Interval Between Minor and Previous Major Eruption



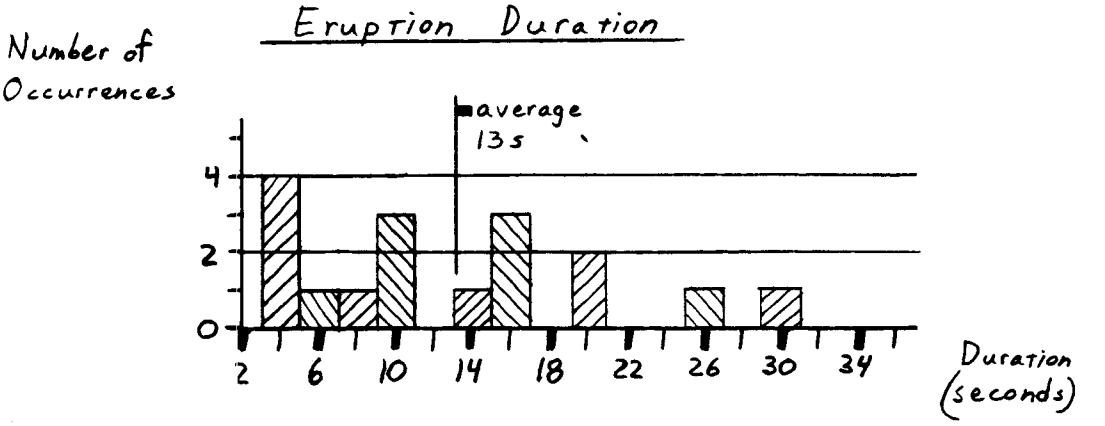
Interval Between Minor and Next Major Eruption



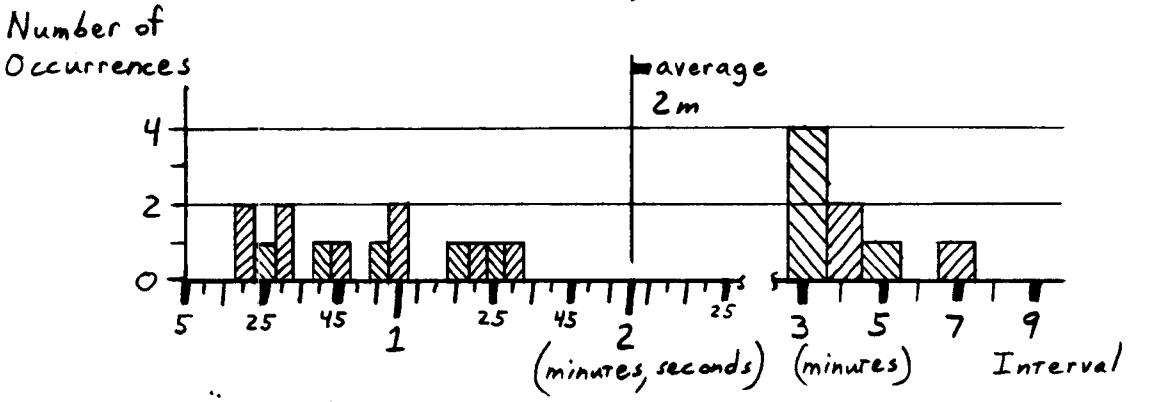
Sunset Lake

May, 1988

Eruption Duration



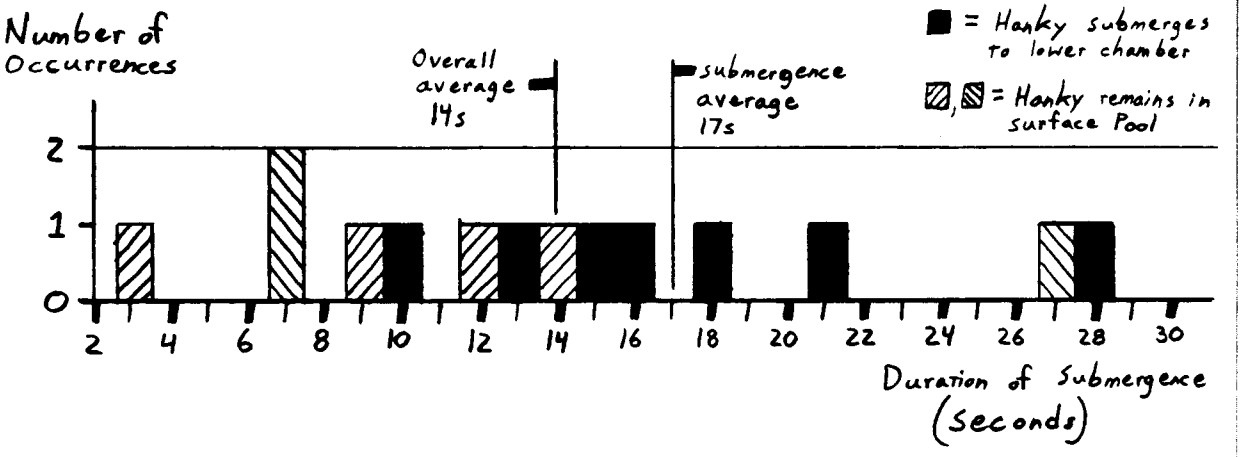
Eruption Interval, within active period



Hankerchief Pool

June 19, 1988

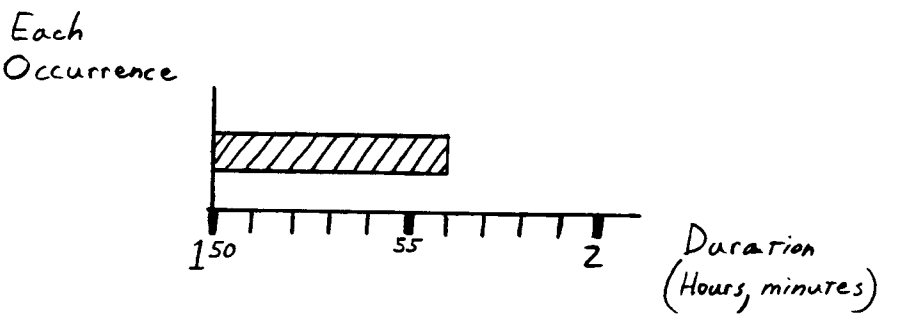
Duration of Submergence of Hankerchief



Spouter Geyser

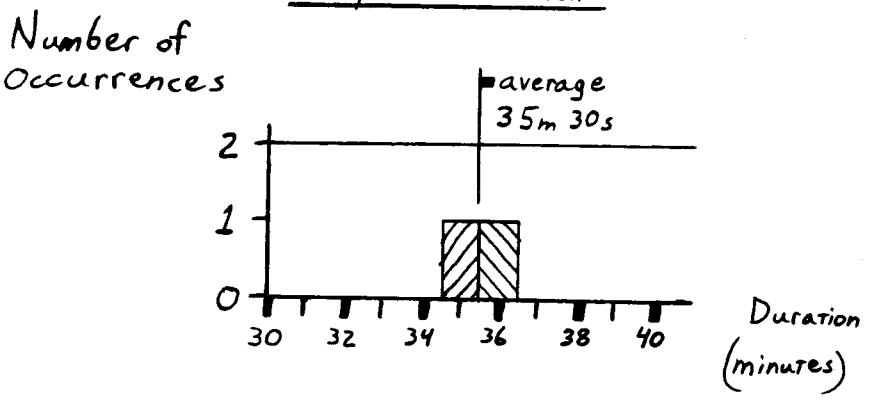
May 26, 1988

Eruption Duration

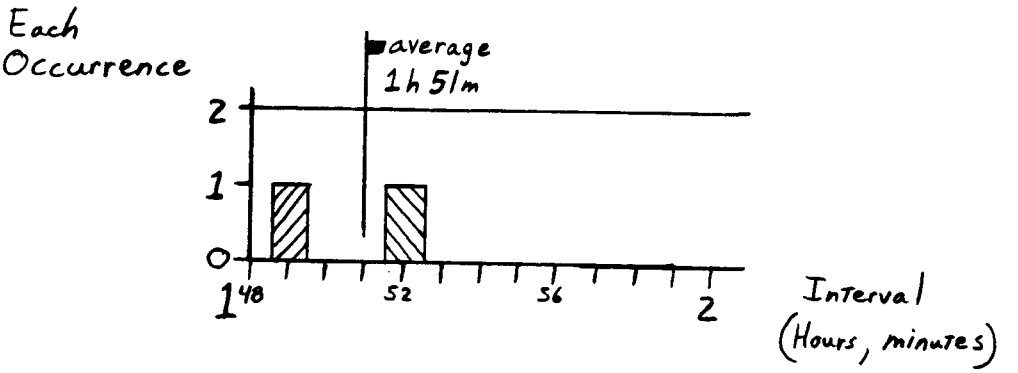


"Refracted Geyser"

Eruption Duration

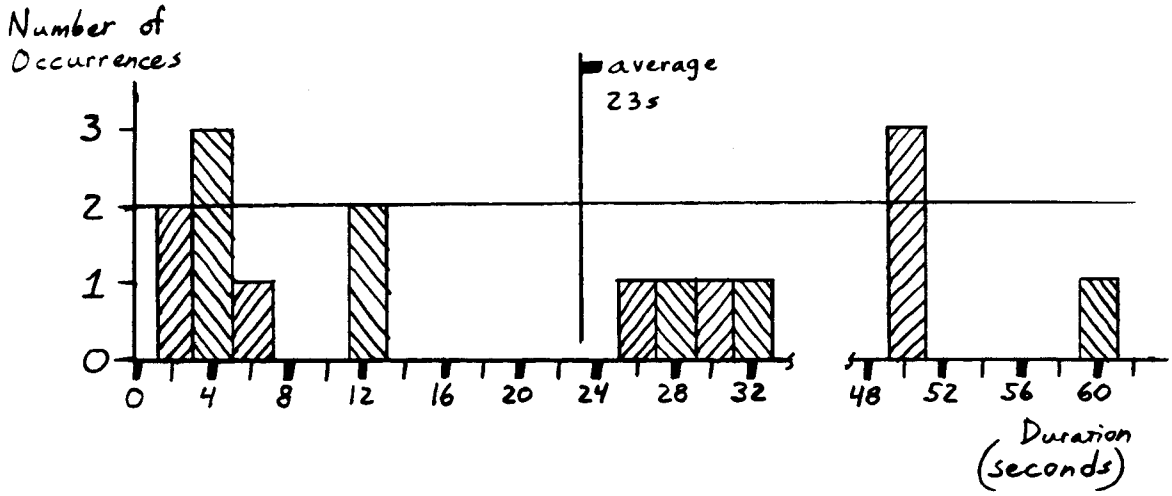


Eruption Interval

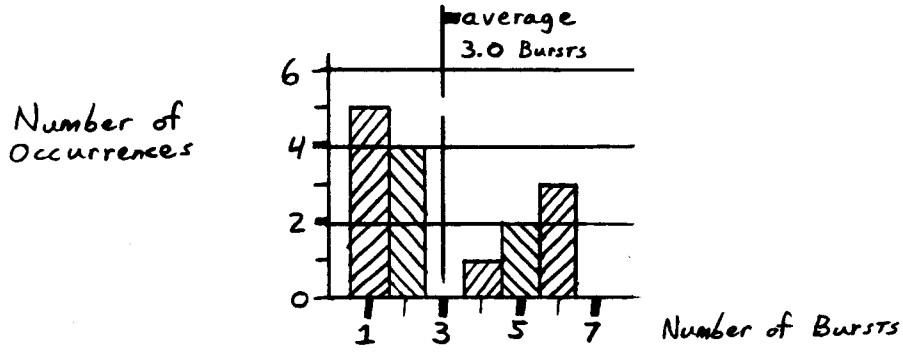


Jewel Geyser
May 16, 1988

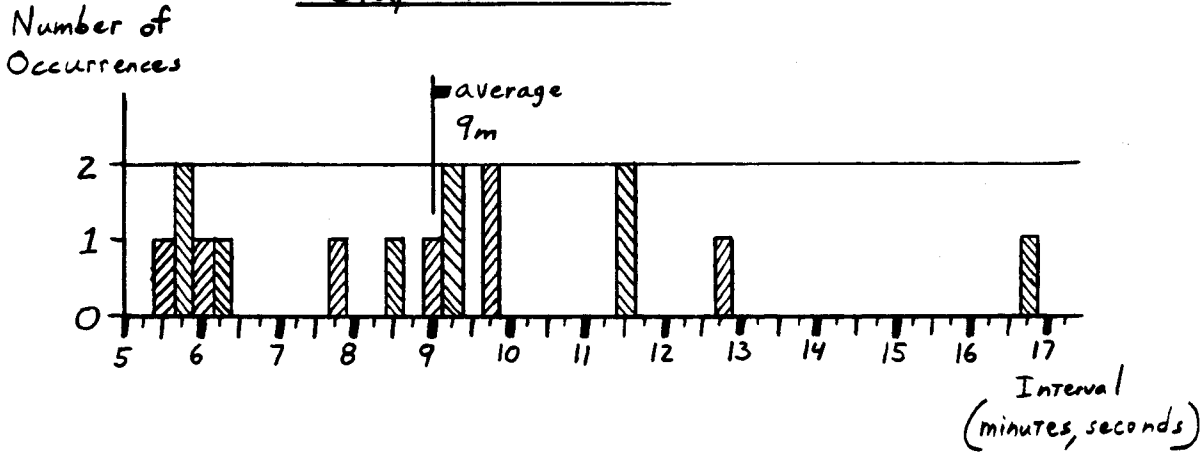
Eruption Duration



Number of Bursts Per Eruption



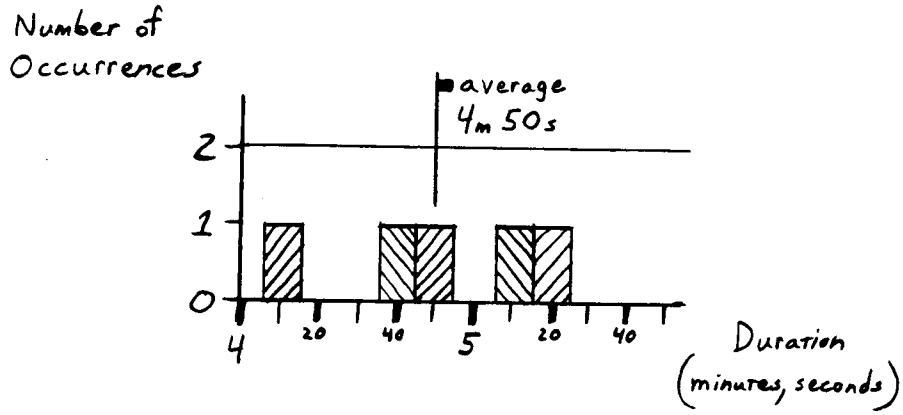
Eruption Interval



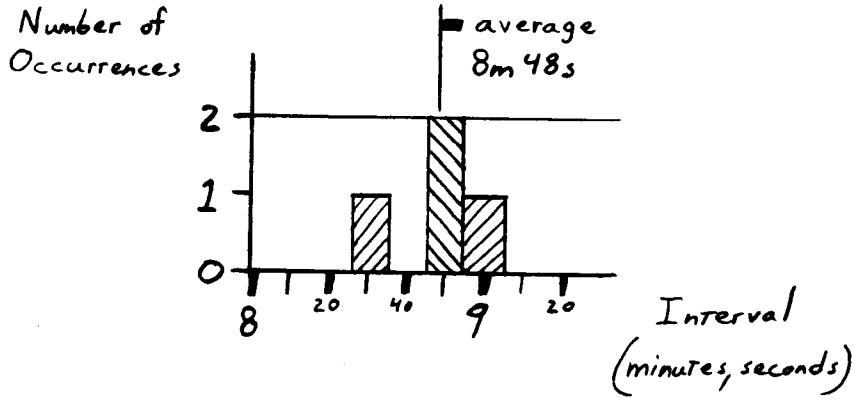
Mustard Spring

May 16, 1988

Eruption Duration



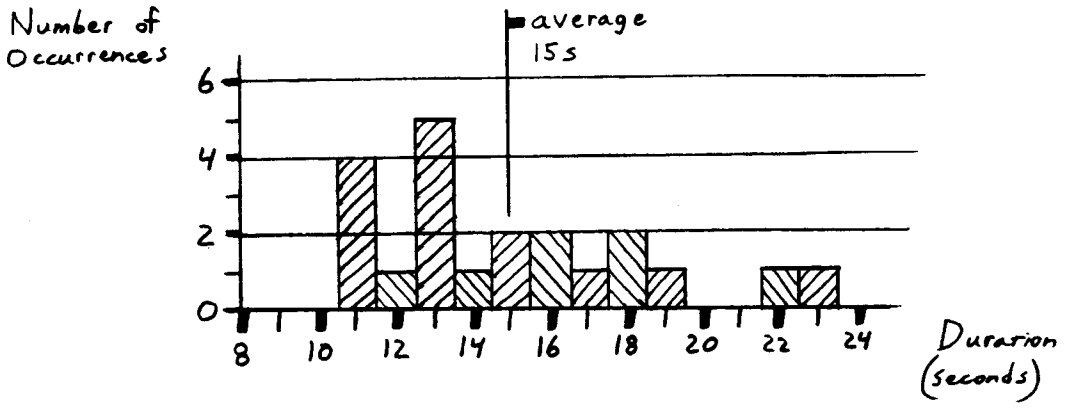
Eruption Interval



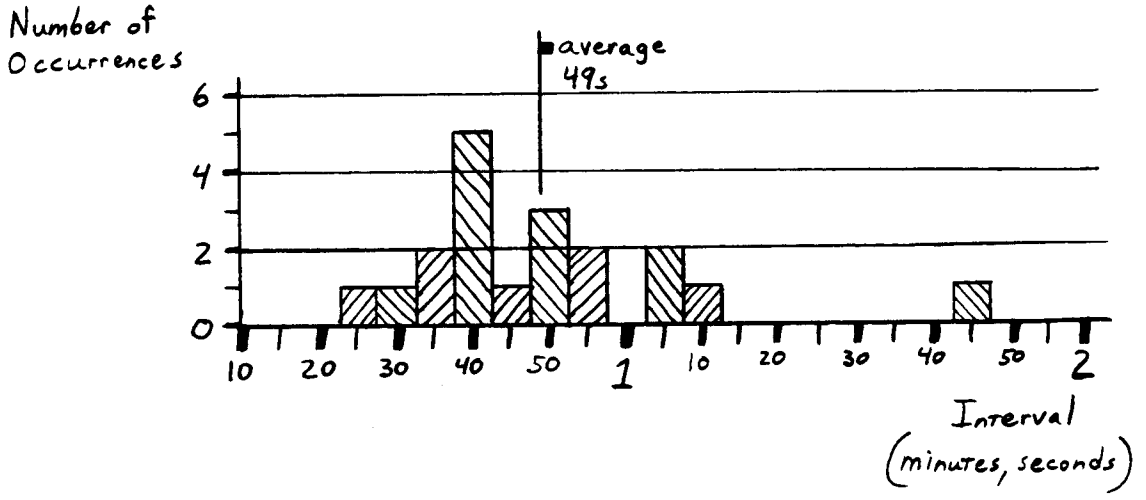
Rusty Geyser

May 16, 1988

Eruption Duration



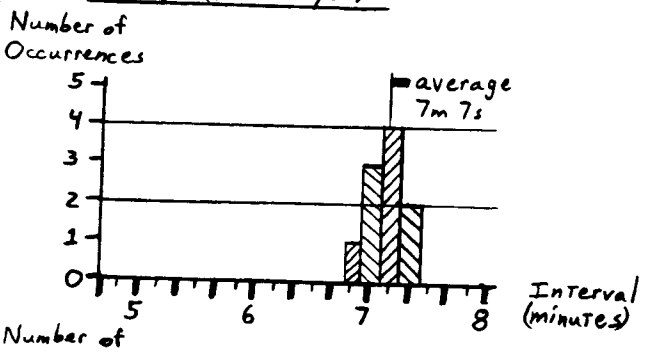
Eruption Interval



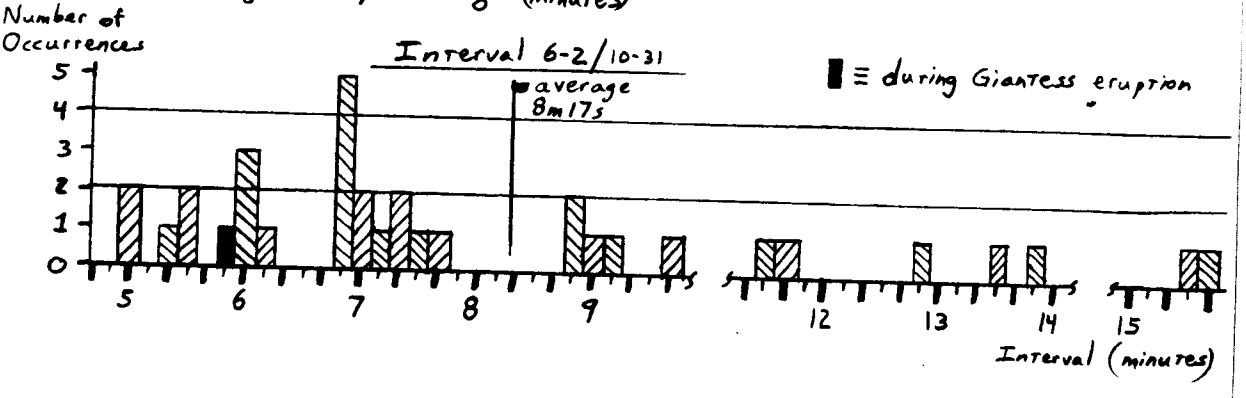
Anemone Geyser

April 26 - October 31, 1988

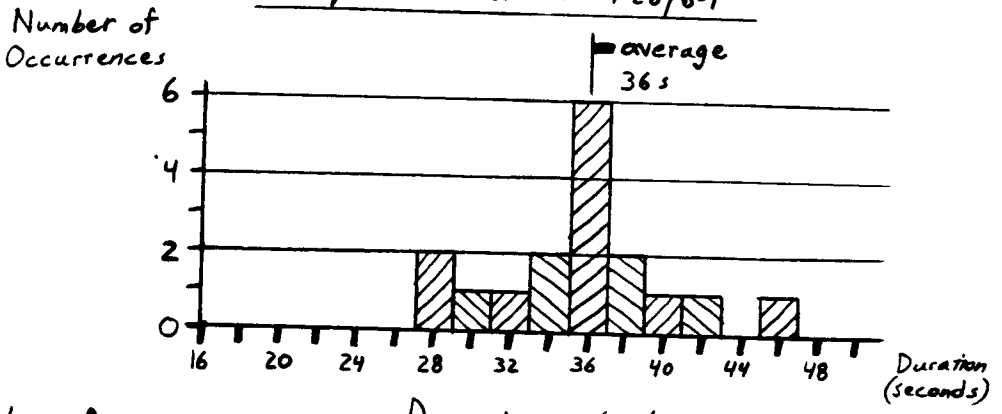
Interval 4-26/6-1



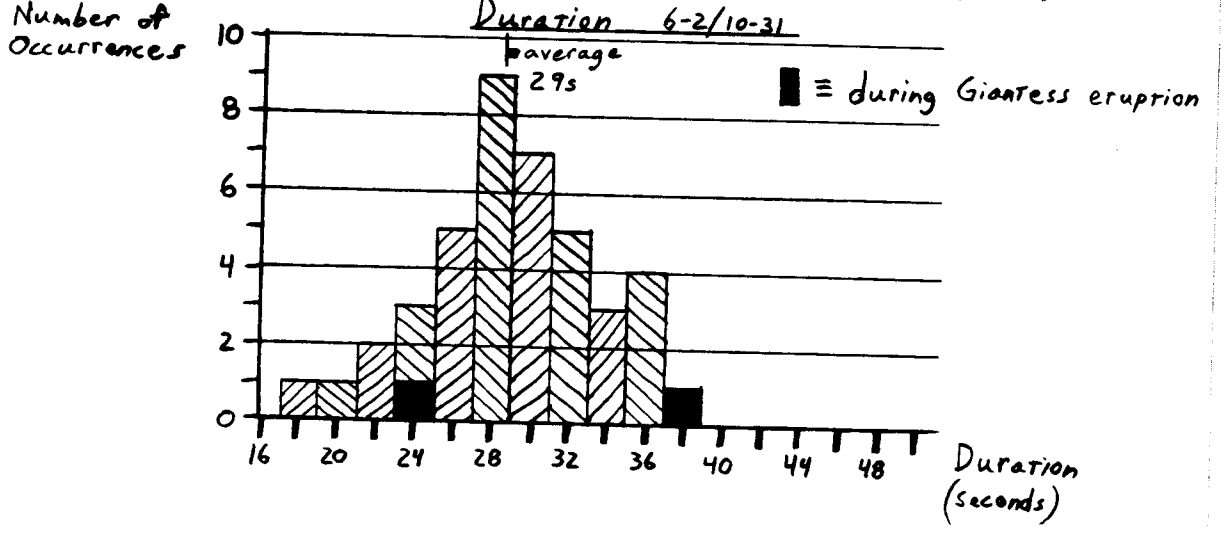
Interval 6-2/10-31



Eruption Duration 4-26/6-1

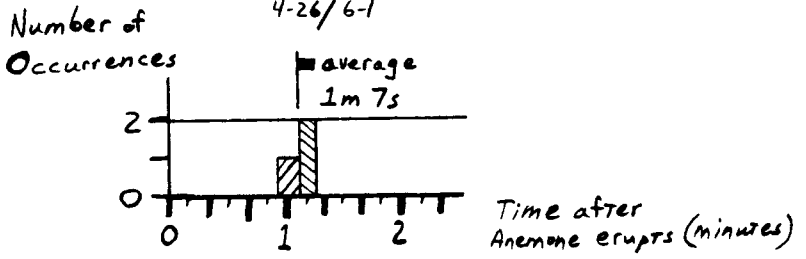


Duration 6-2/10-31

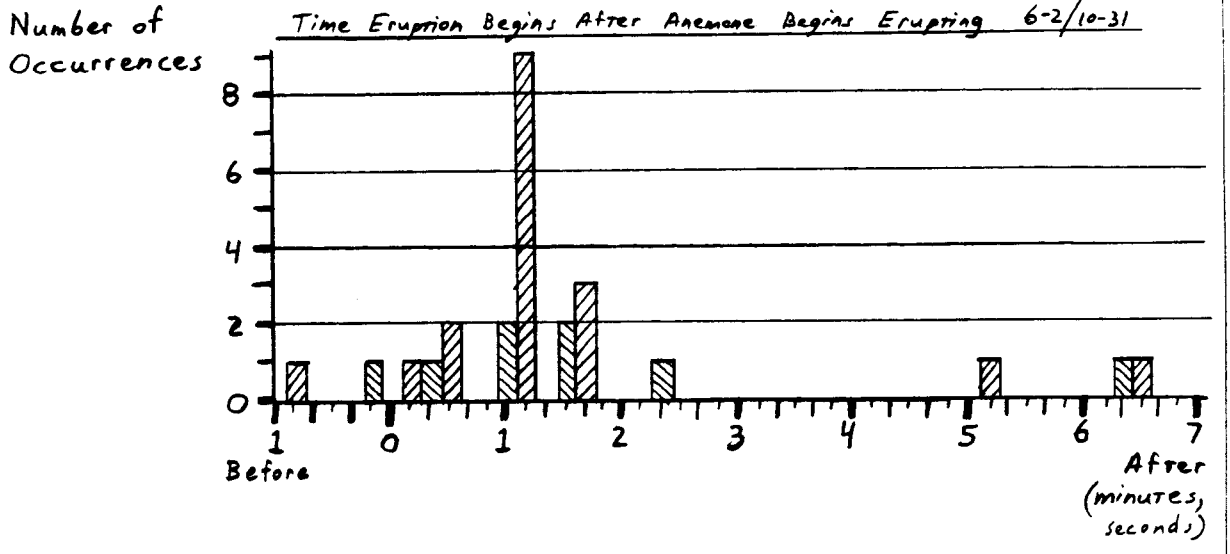


Little Anemone Geyser
April 26 - October 31, 1988

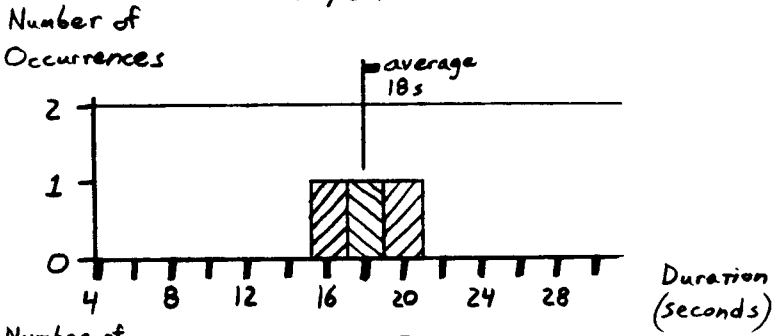
Time Eruption Begins After Anemone Begins Erupting
4-26/6-1



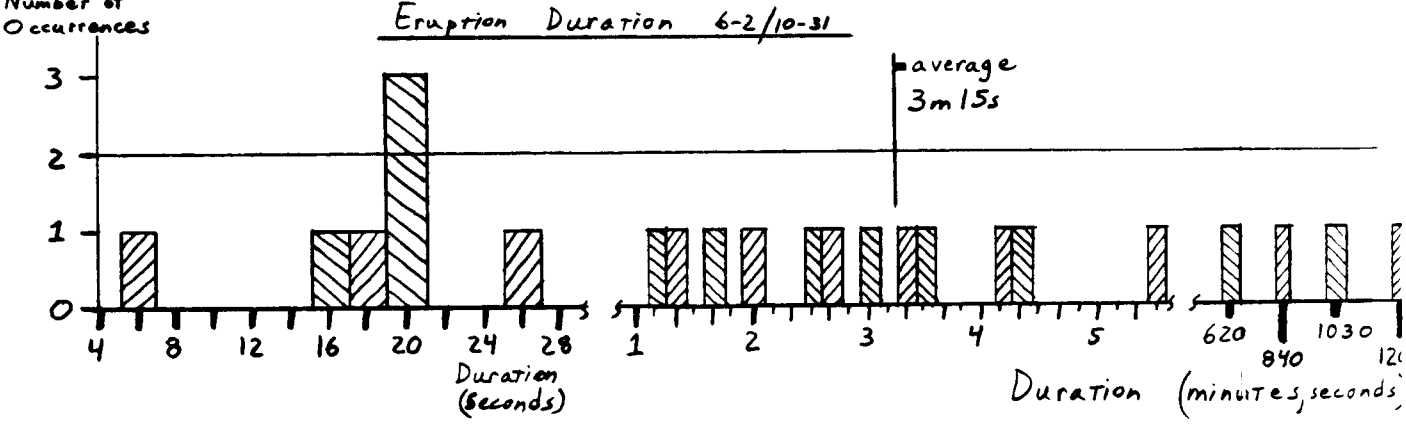
Time Eruption Begins After Anemone Begins Erupting 6-2/10-31



Eruption Duration
4-26/6-1

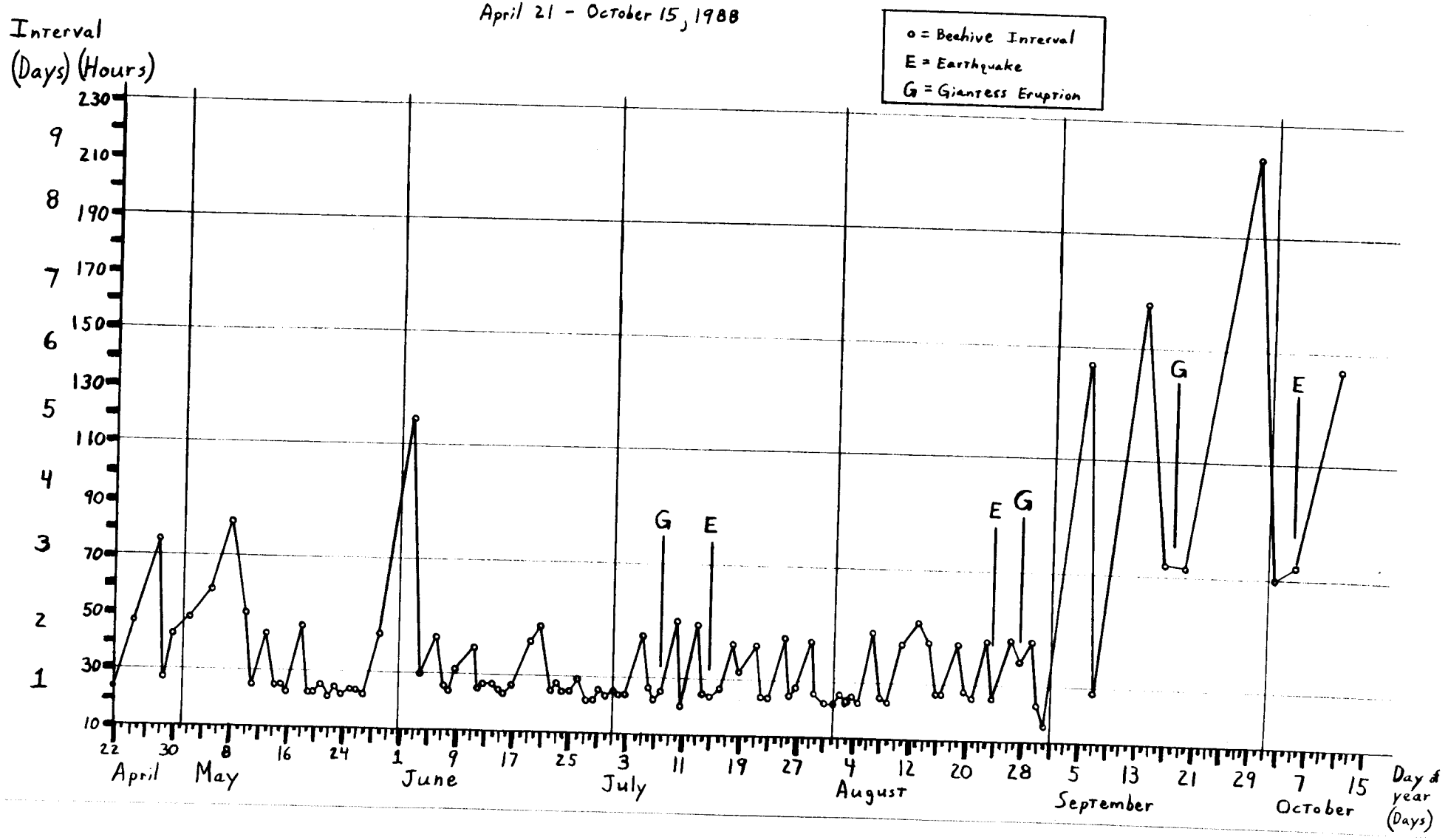


Eruption Duration 6-2/10-31



Beehive Eruption Intervals
vs.
Day of the Year

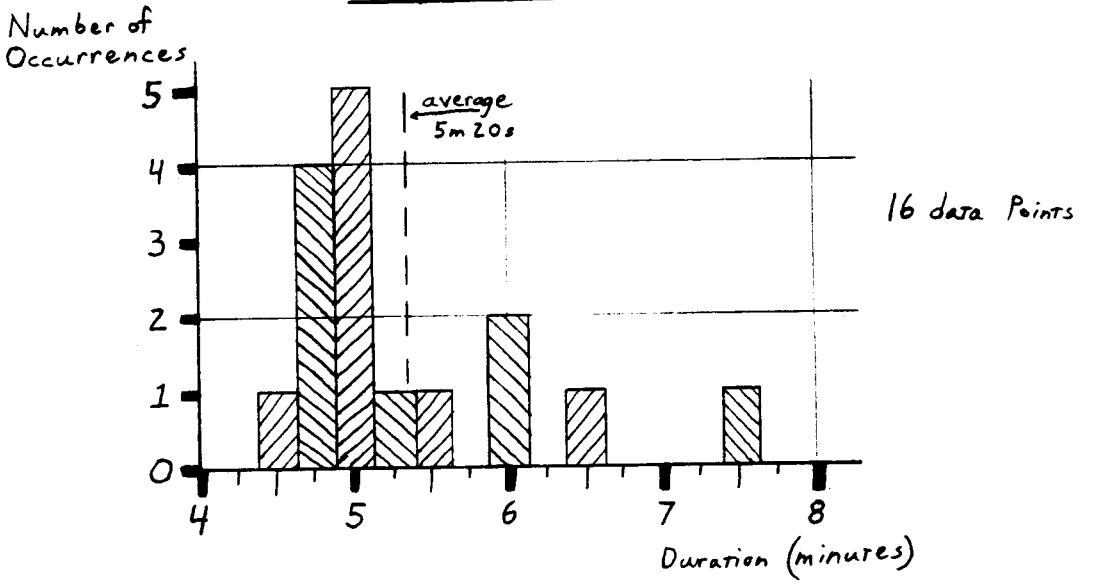
April 21 - October 15, 1988



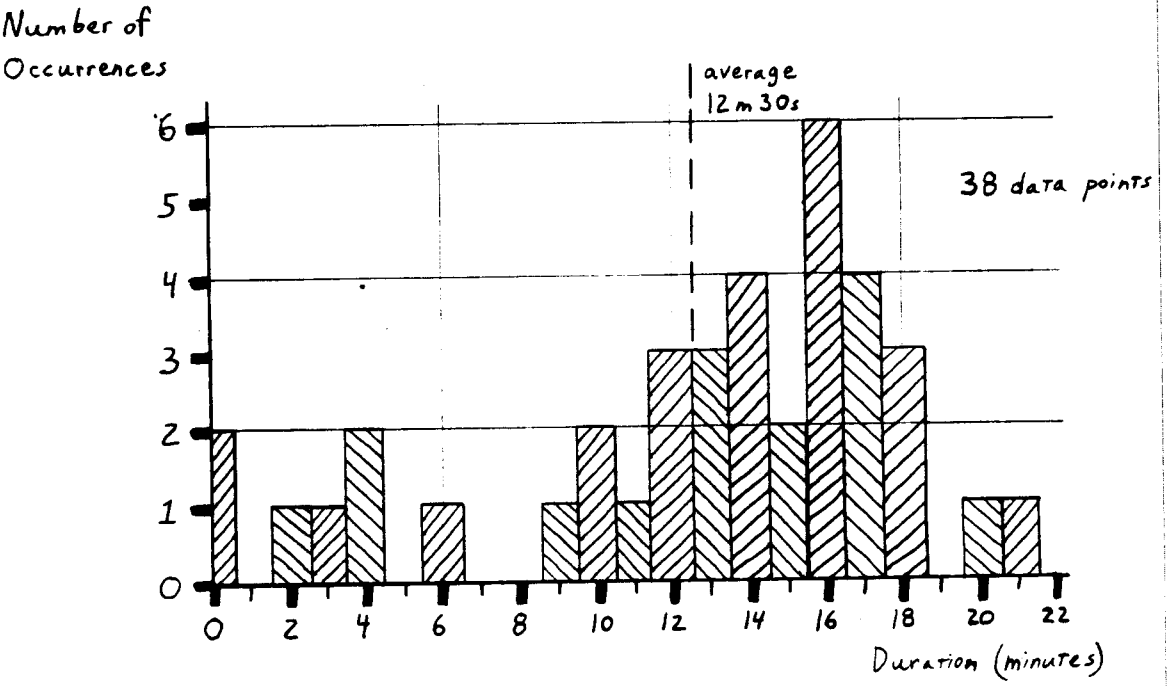
Beehive Geyser

April 21 - October 11, 1988

Eruption Duration



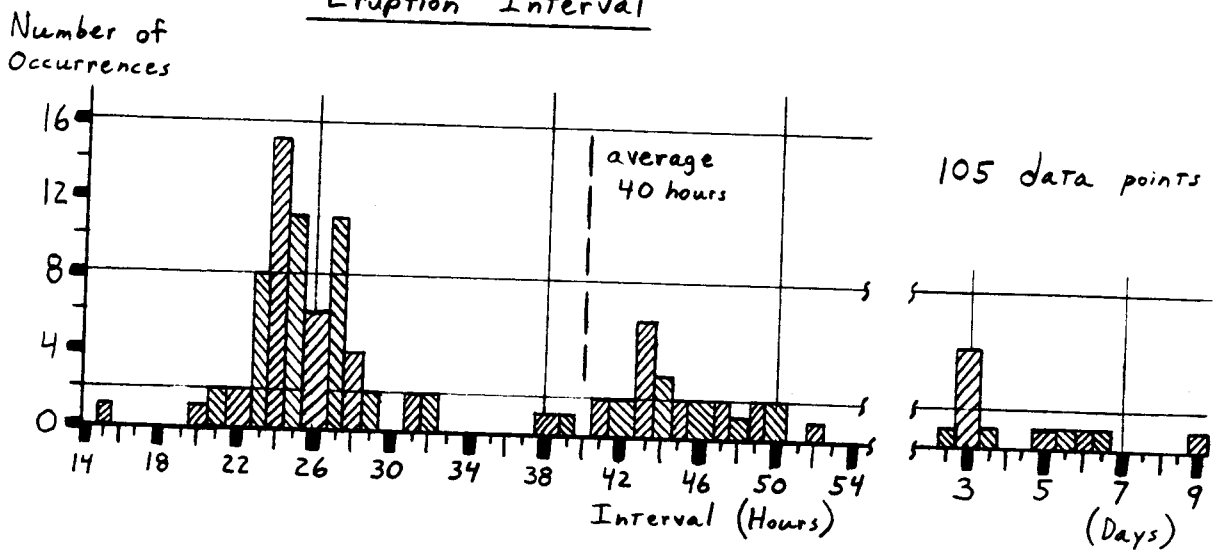
Indicator Duration Prior to Beehive Eruption



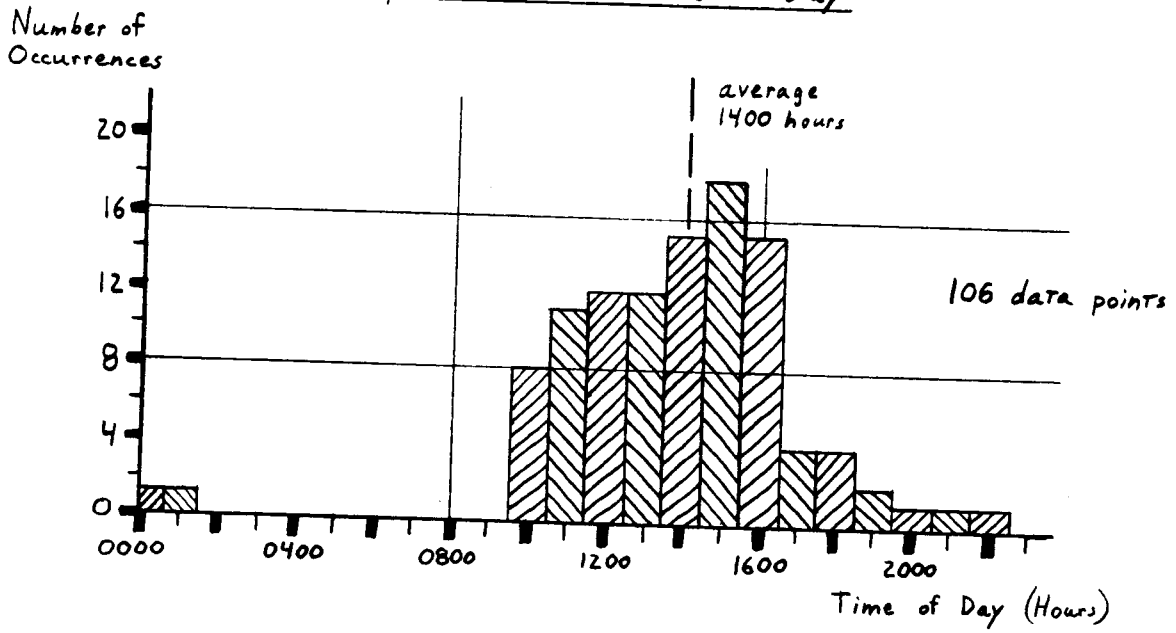
Beehive Geyser

April 21 - October 11, 1988

Eruption Interval



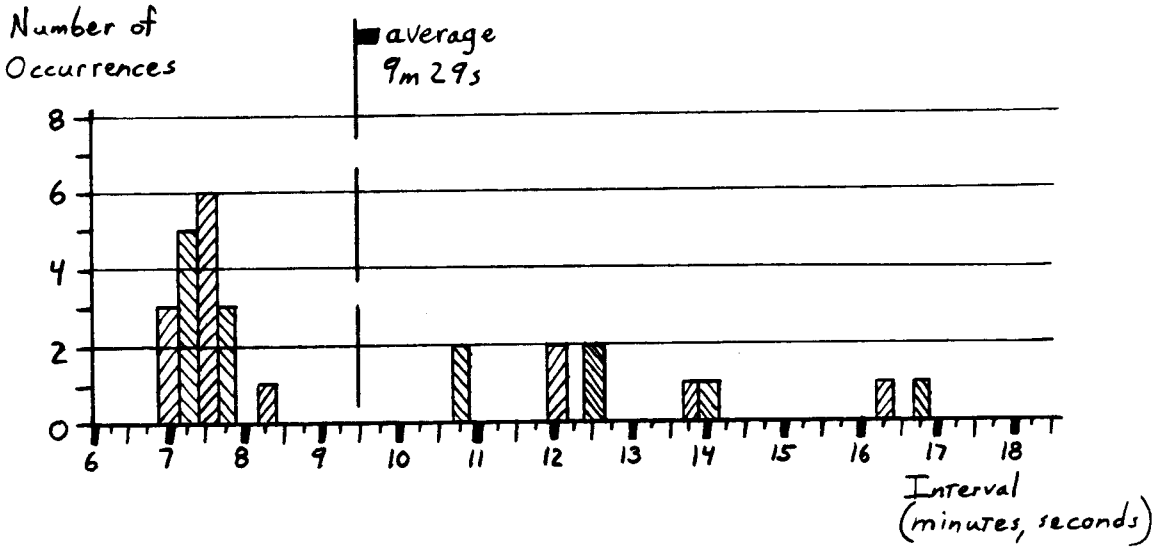
Eruptions vs. Time of Day



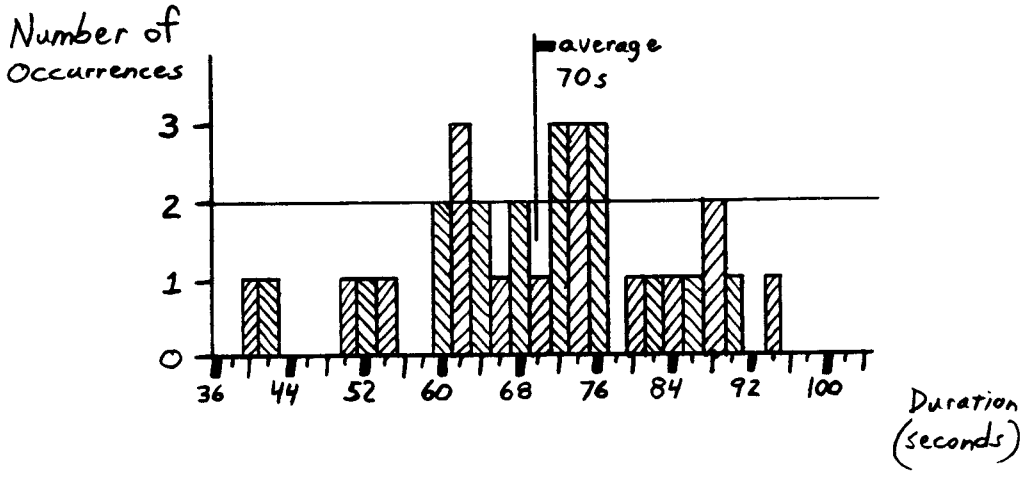
Bronze Spring

September 6 – November 5, 1988

Eruption Interval

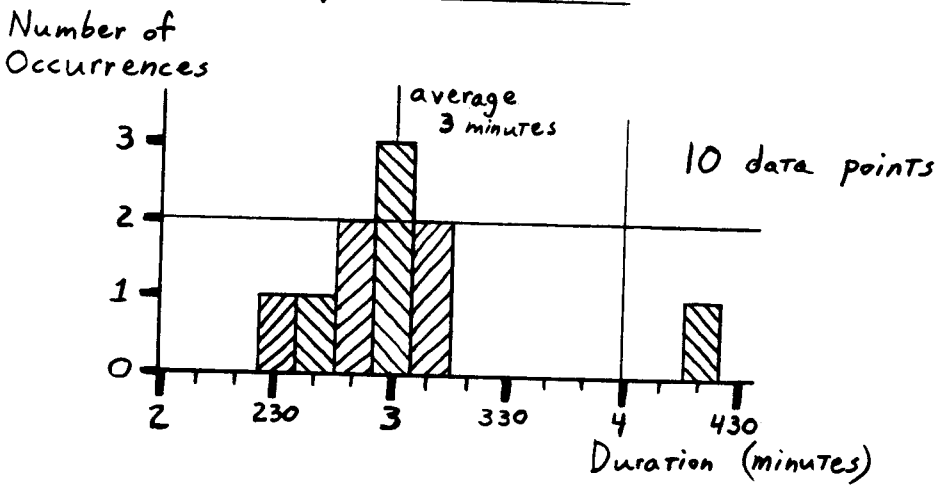


Eruption Duration

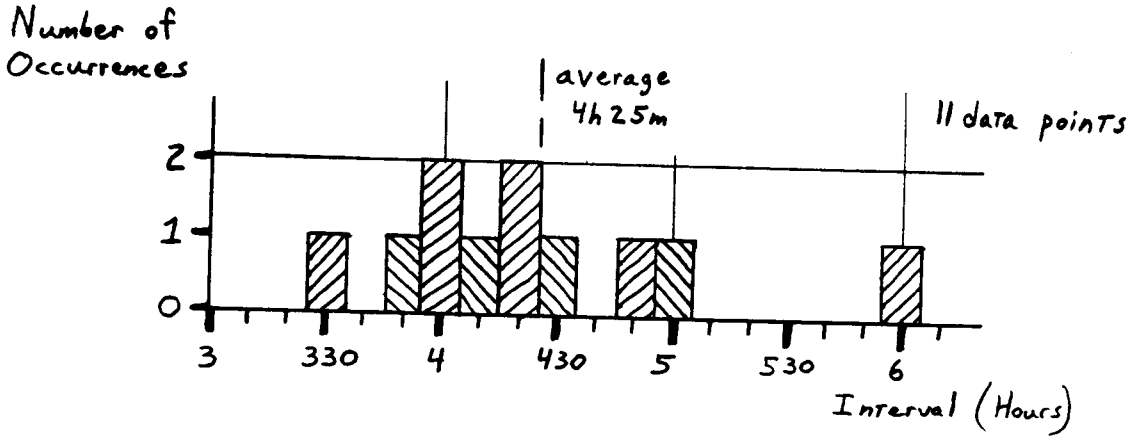


Depression Geyser
May - September, 1988

Eruption Duration



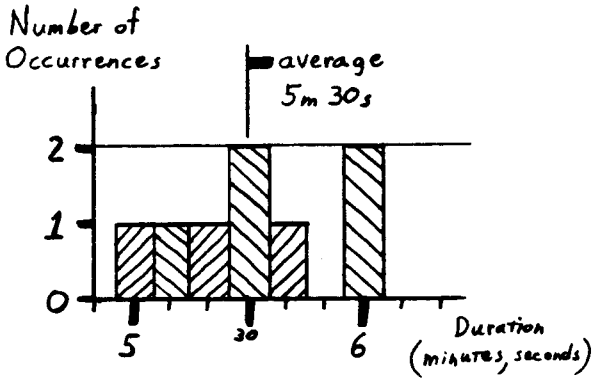
Eruption Interval



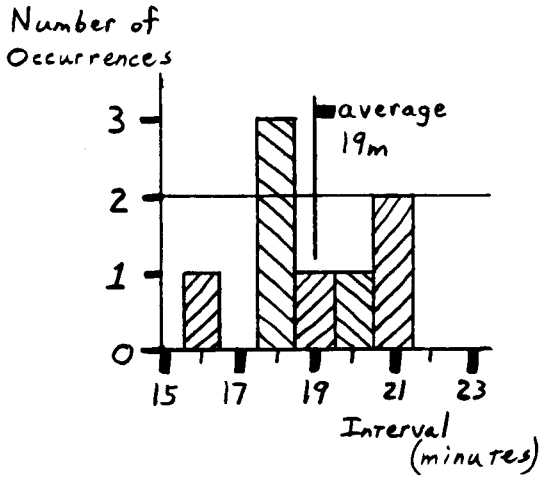
Dome Geyser

April 26 - November 4, 1988

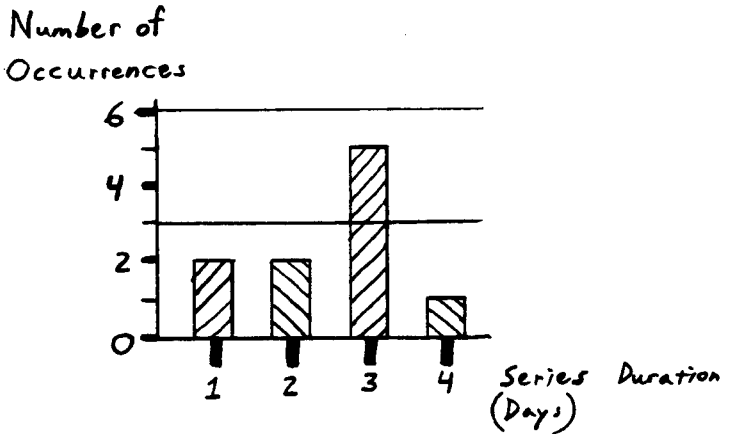
Eruption Duration Within Eruption Series



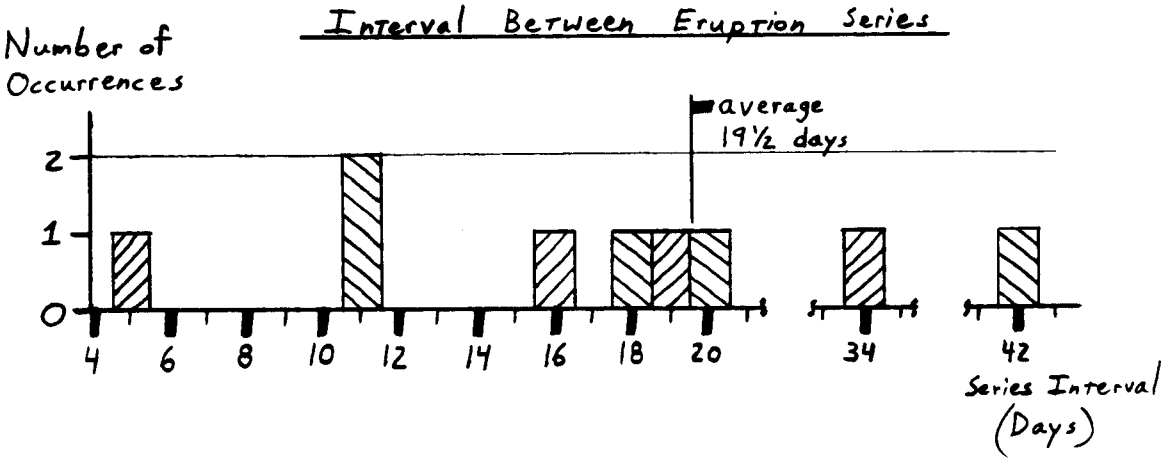
Eruption Interval Within Eruption Series



Approximate Duration of Eruption Series



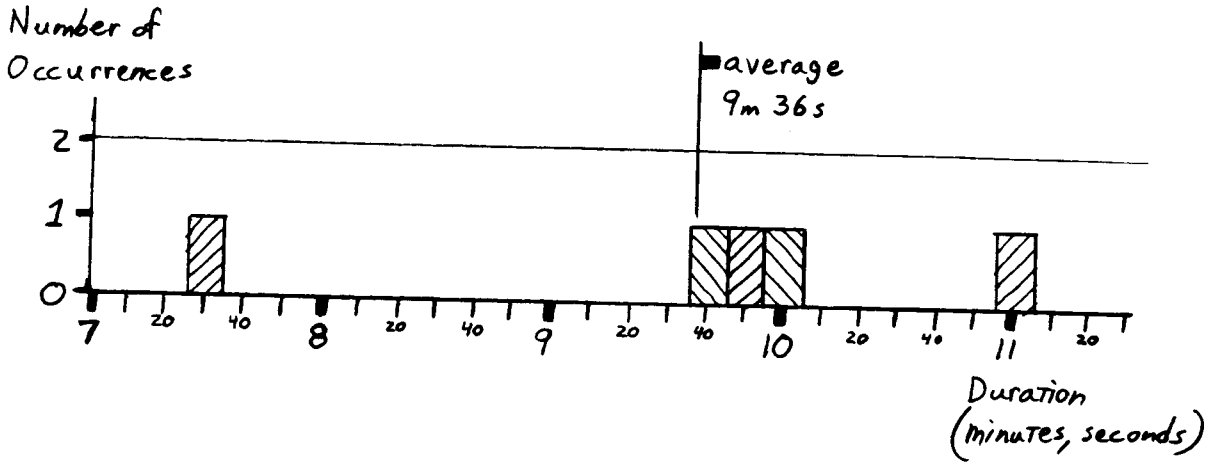
Interval Between Eruption Series



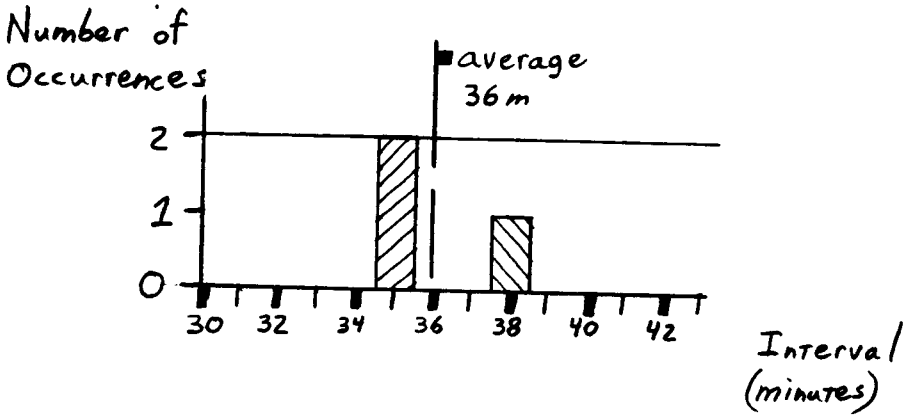
Doublet Pool

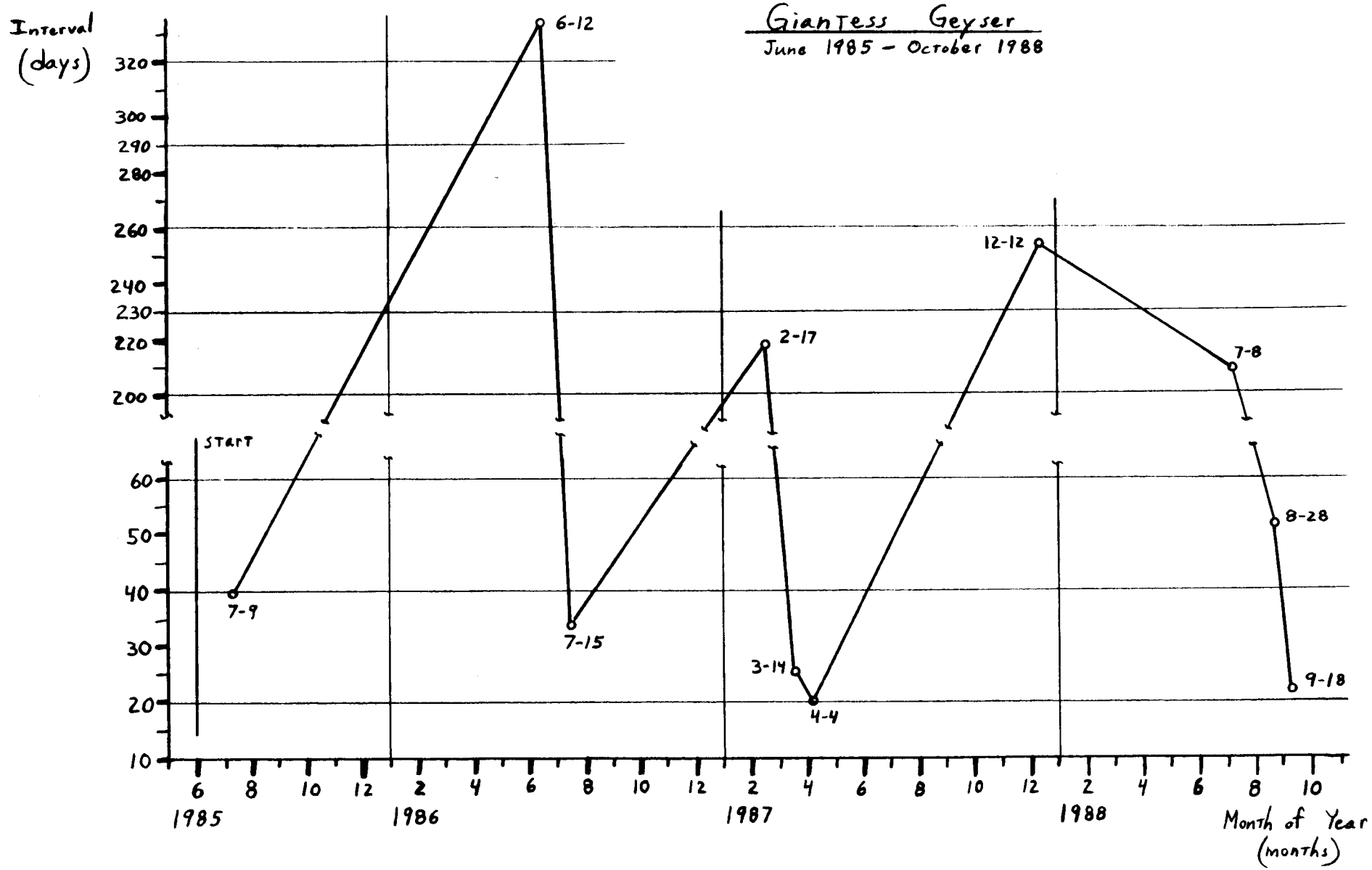
May 1 - October 30, 1988

Activity (Thumping) Duration



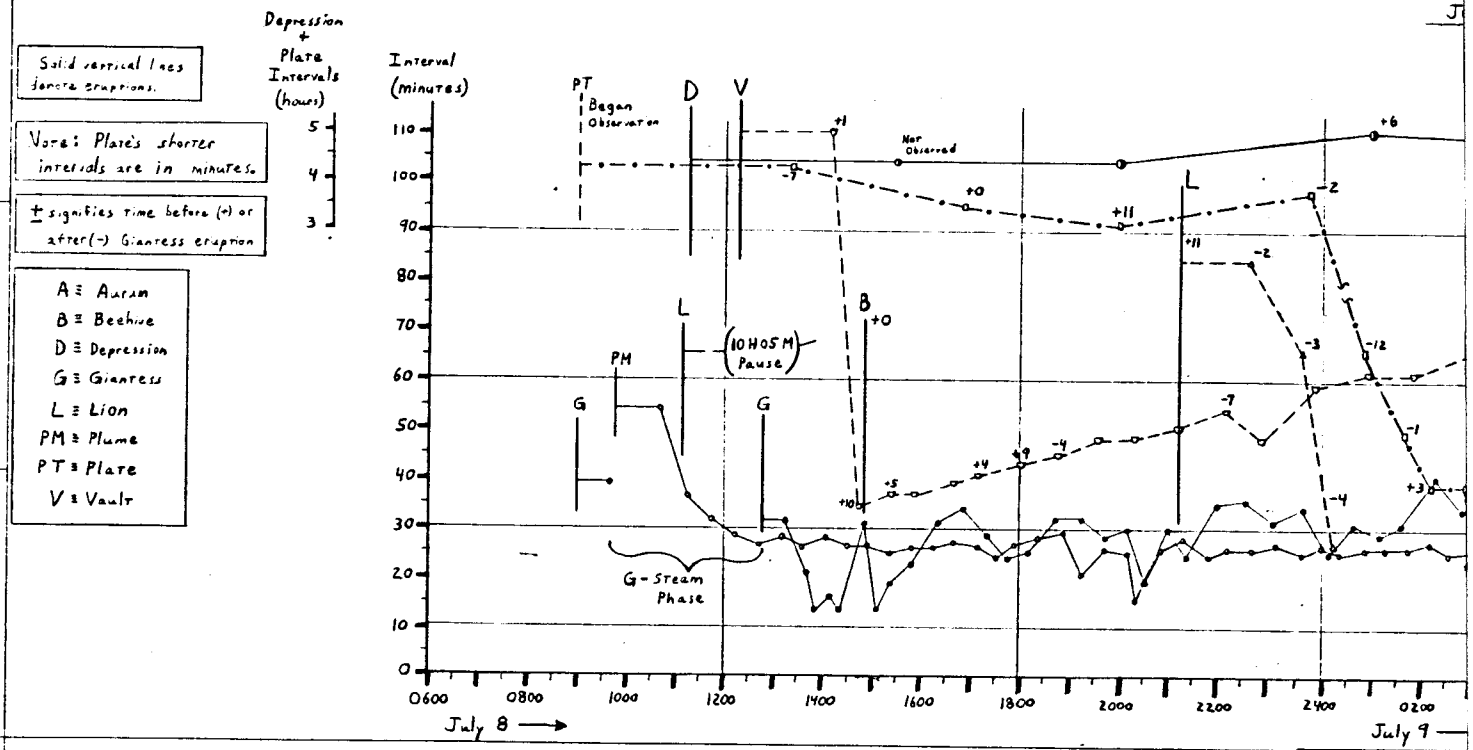
Activity (Thumping) Interval




Interval
(days)
Giantess Geyser
June 1985 – October 1988
320
300
290
280
260
240
230
220
200
START
60
50
40
30
20
10
6-12
7-9
7-15
2-17
3-14
4-4
12-12
7-8
8-28
9-18
6
8
10
12
2
4
6
8
10
12
2
4
6
8
10
12
2
4
6
8
10
1985
1986
1987
1988
Month of Year
(months)

Geyse

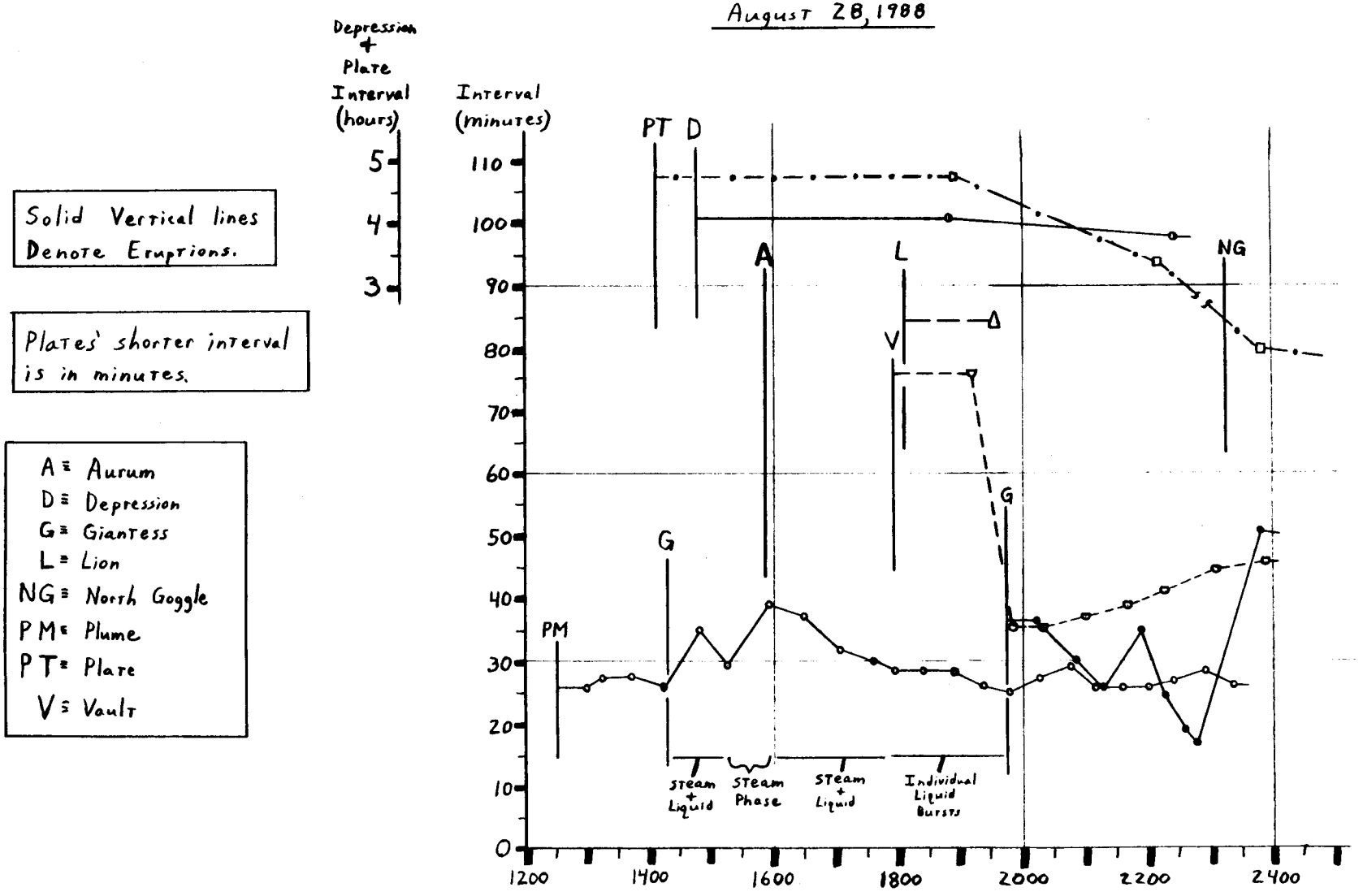
J



Page 230

Geyser Hill Activity

August 28, 1988



Solid Vertical lines Denote Eruptions.

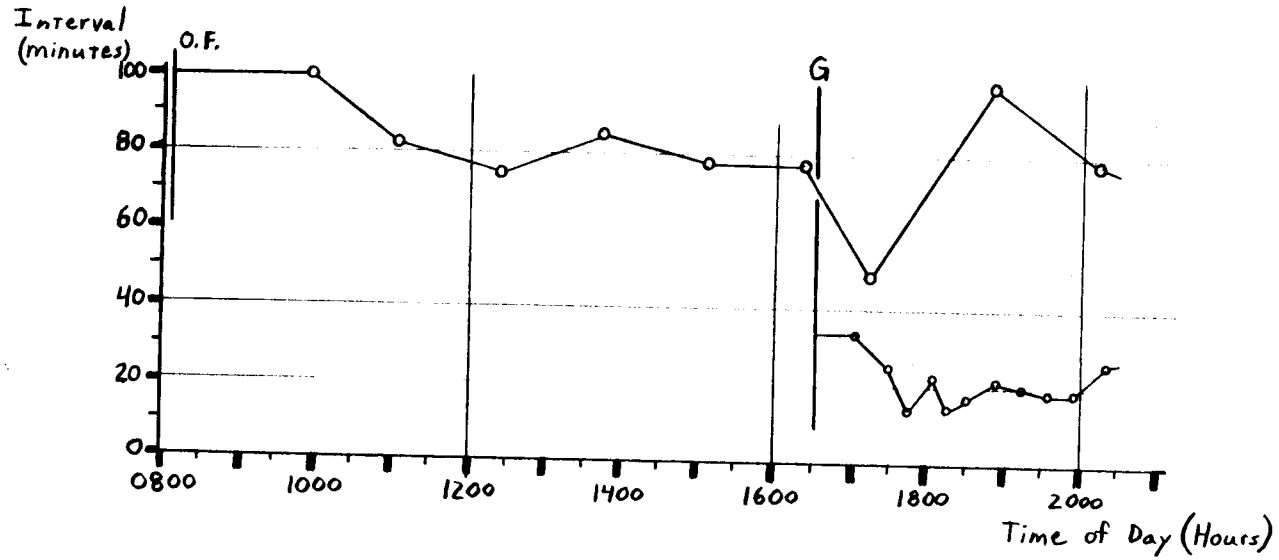
Plates' shorter interval is in minutes.

A ≡ Aurum
D ≡ Depression
G ≡ Giantess
L ≡ Lion
NG ≡ North Goggle
PM ≡ Plume
PT ≡ Plate
V ≡ Vault

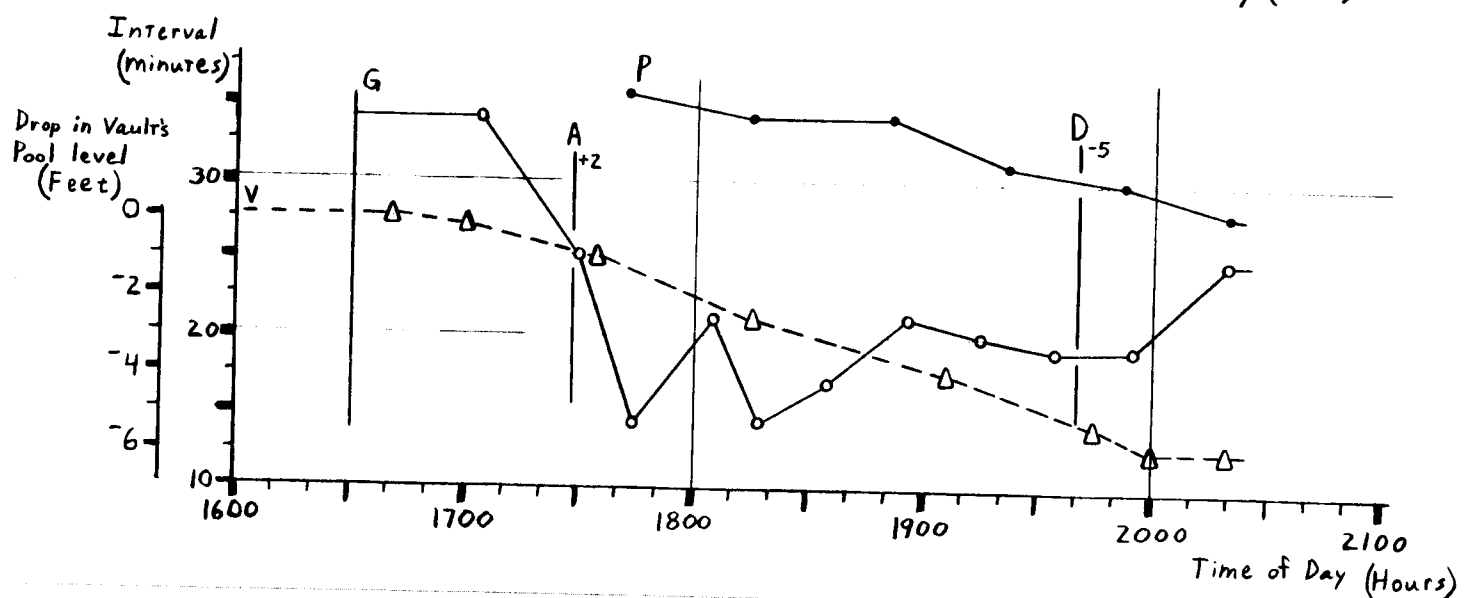
Geyser Hill and Old Faithful Activity September 18, 1988

G = Giantess
O.F. = Old Faithful

Solid lines denote eruptions.

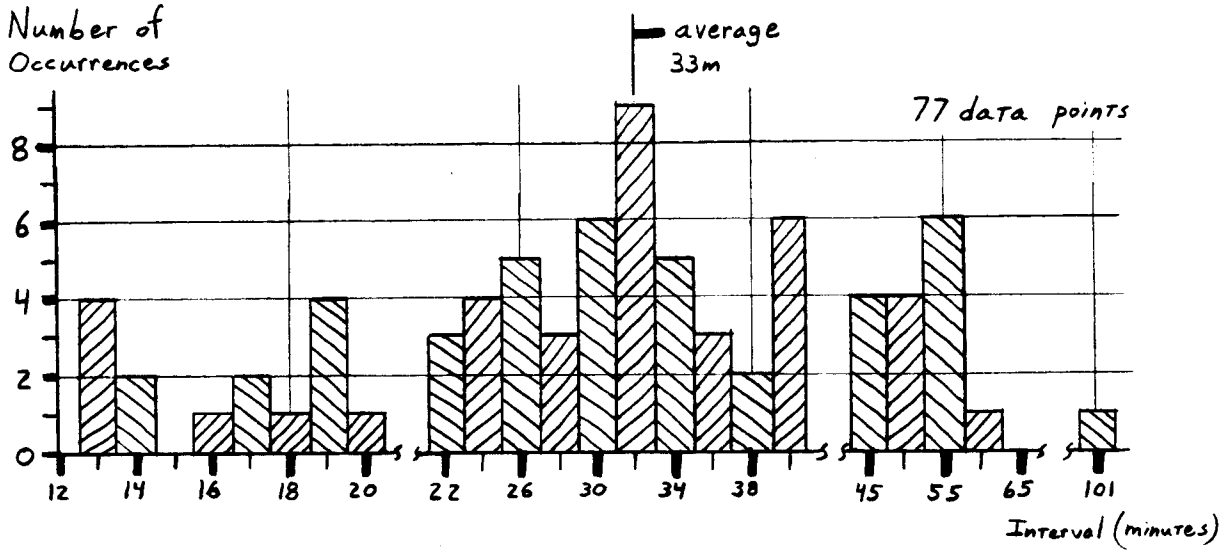


A = Aurum
D = Depression
G = Giantess
P = Plume
V = Vault

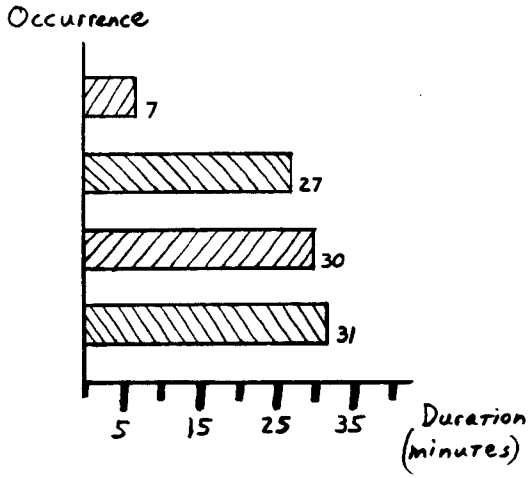


Giantess Geyser
July 8 - September 19, 1988

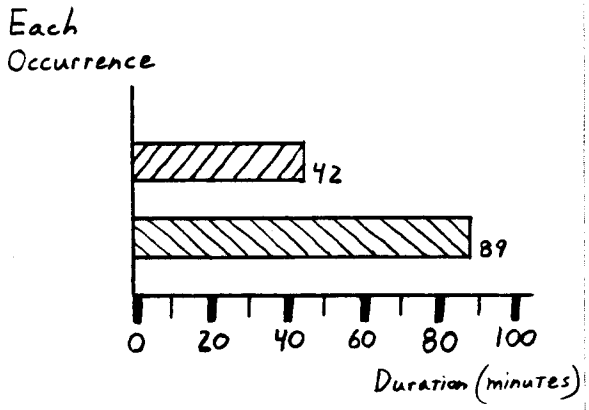
Eruption Interval Within a series of Eruptions



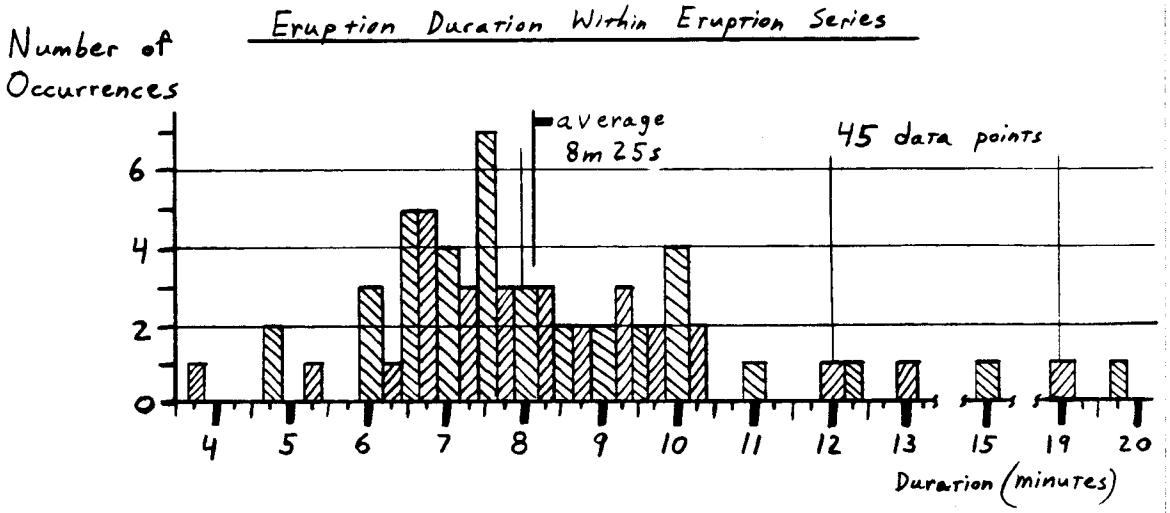
Eruption Durations Preceding Series Eruptions (Initial Eruptions)



Stream Phase Duration

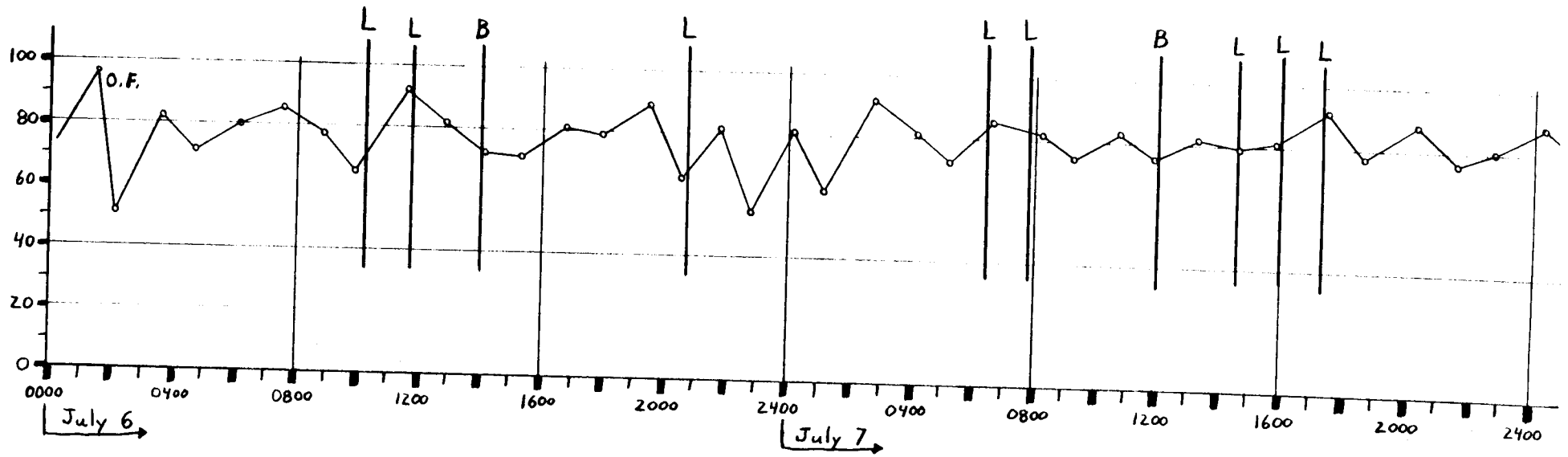


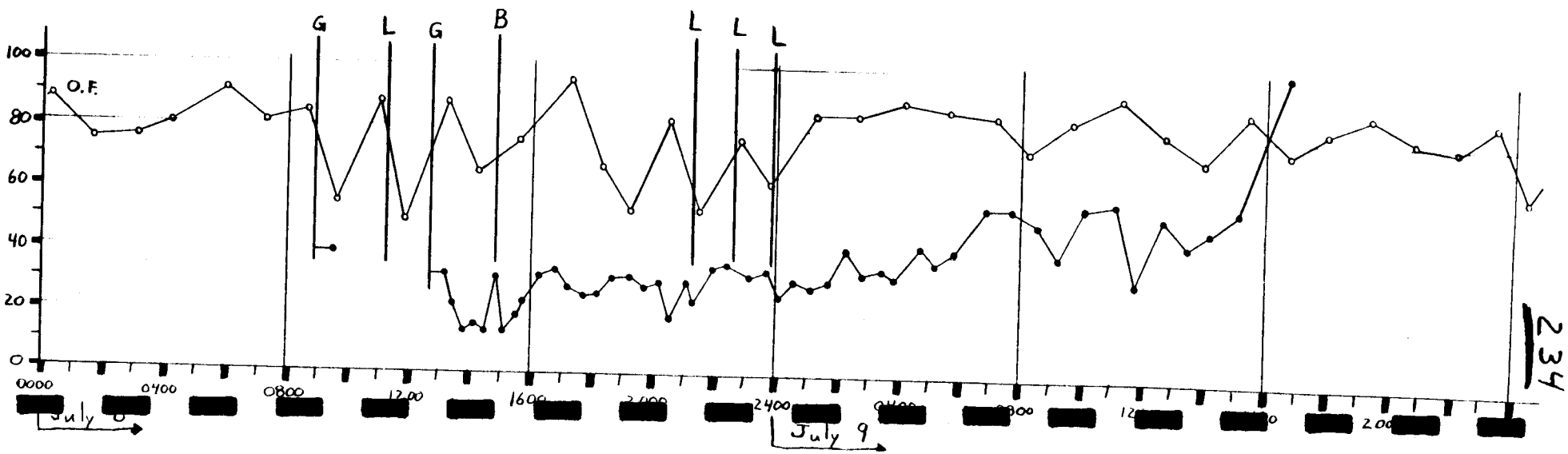
Eruption Duration Within Eruption Series



Old Faithful, Giantess, Beehive, and Lion Geyser Activity
July 6-9, 1988

B = Beehive L = Lion
G = Giantess O.F. = old Faithful





Eruption Intervals for Old Faithful + Giantess

July 8 + 9, 1988

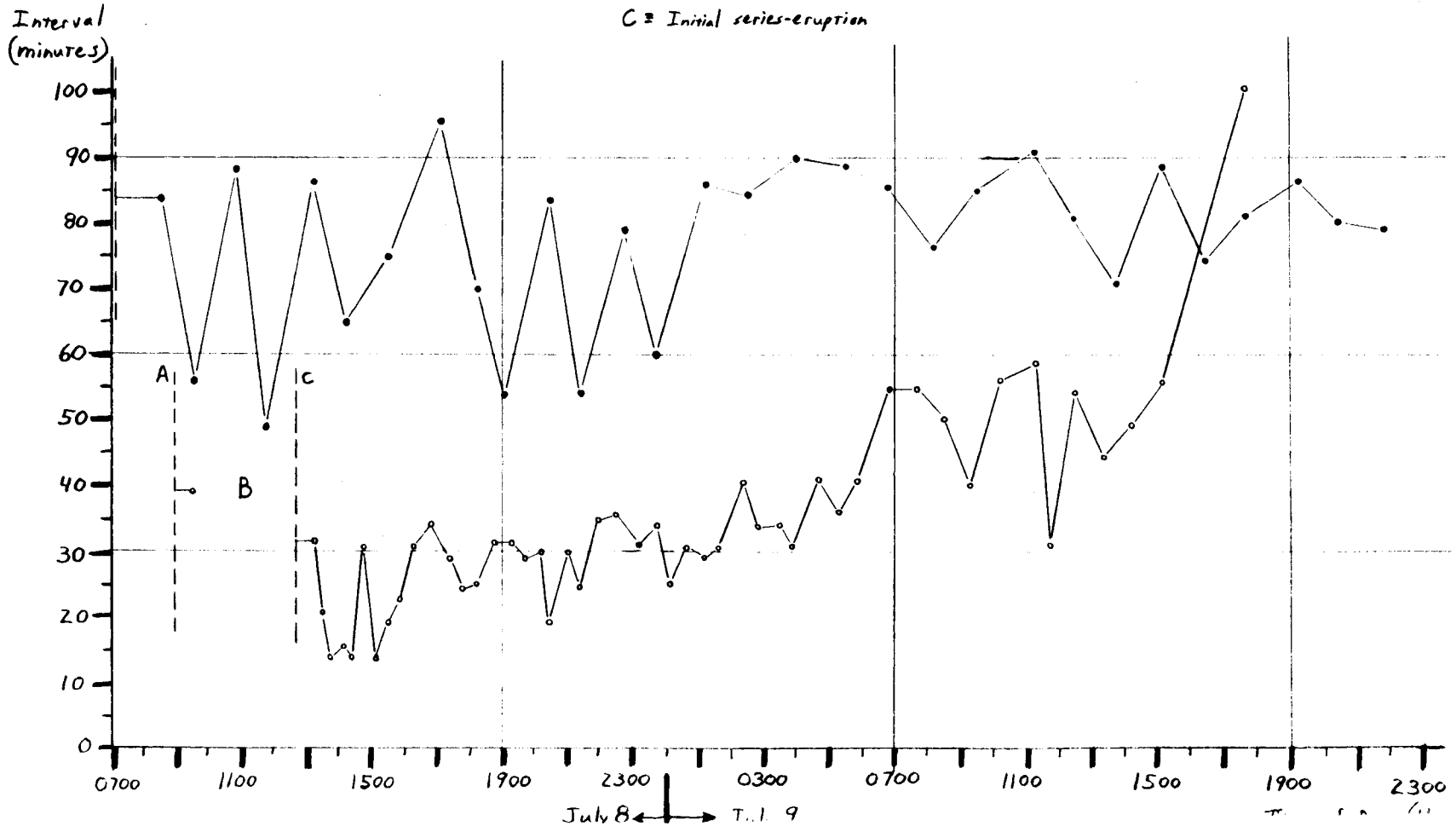
● ≡ Old Faithful Intervals

○ ≡ Giantess Intervals

A ≡ Initial Eruption

B ≡ steam phase

C ≡ Initial series-eruption

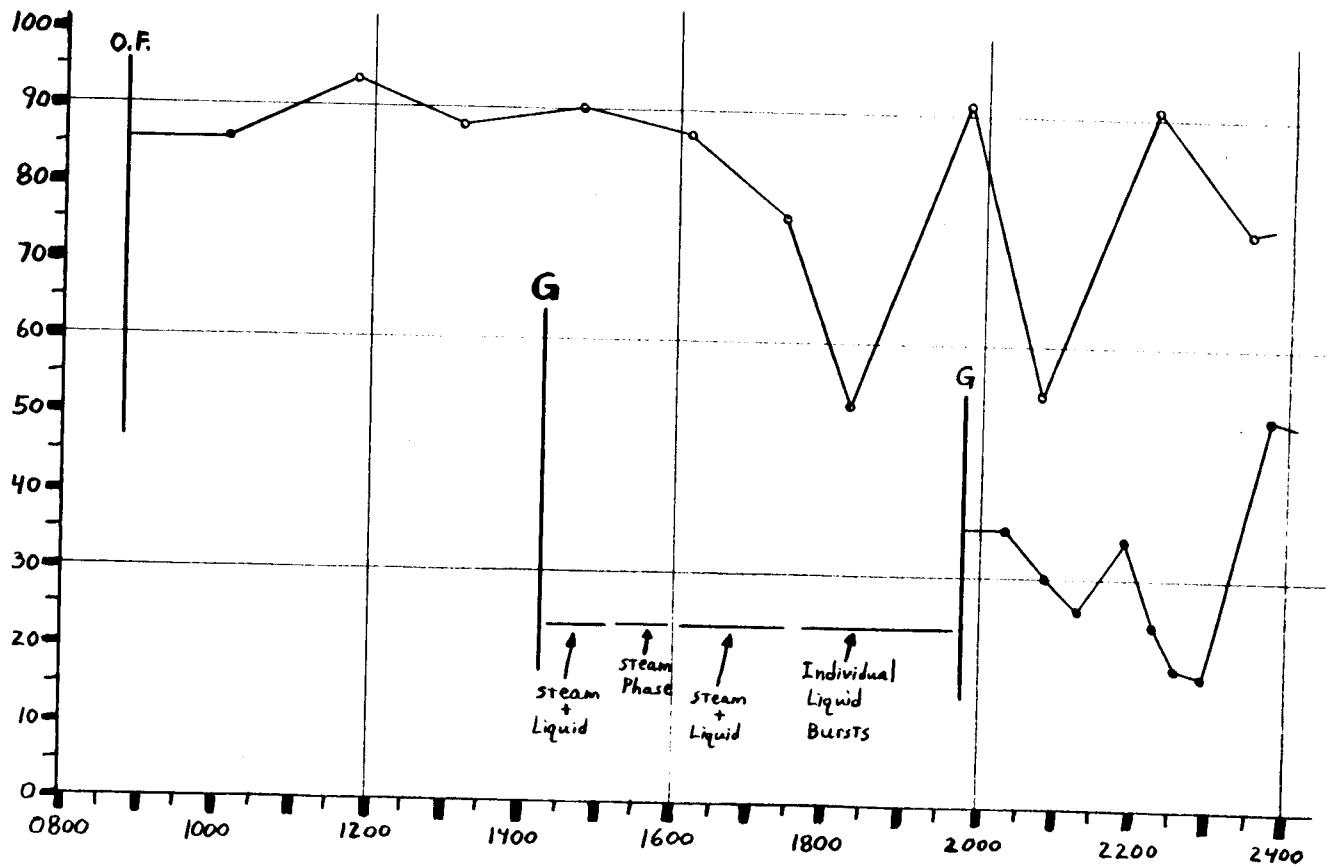


Giantess and Old Faithful Intervals

August 28, 1988

G = Giantess
O.F. = Old Faithful

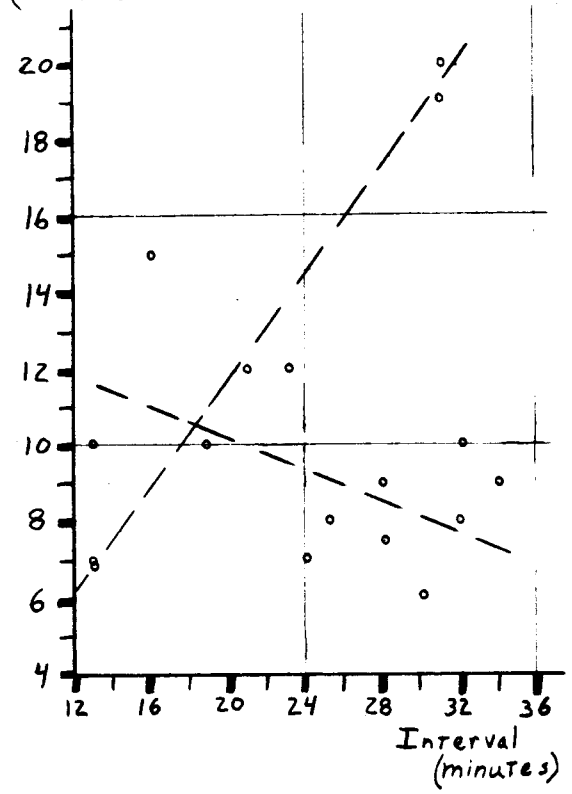
Solid lines denote eruptions.



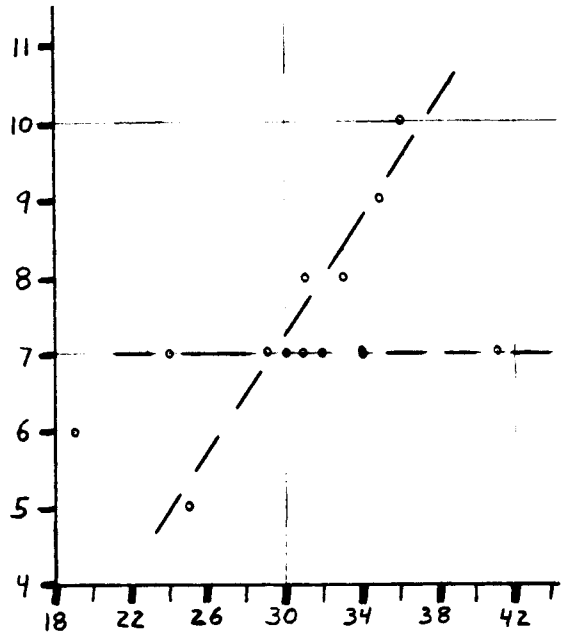
Giantess Geyser

Eruption Duration vs. Interval following that Duration

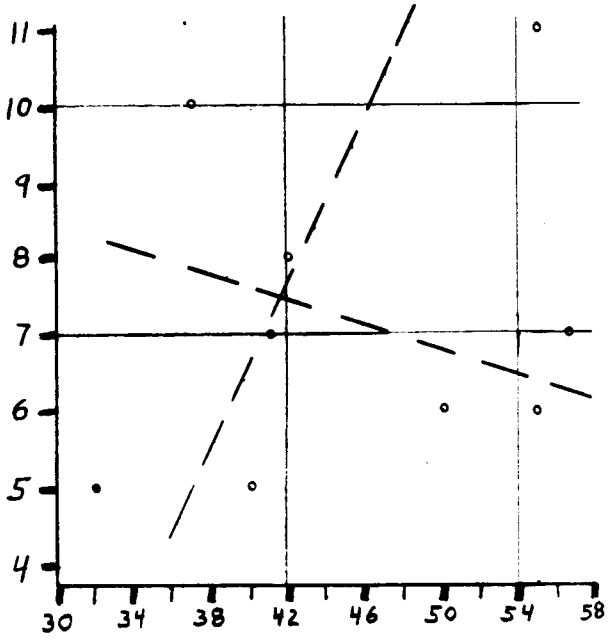
July 8
(1244-2012)



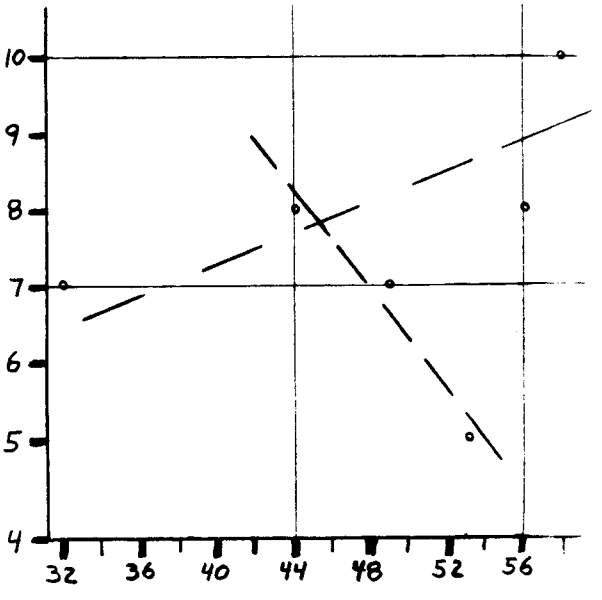
July 8, 9
(2012 - 0326)



July 9
(0326-1014)



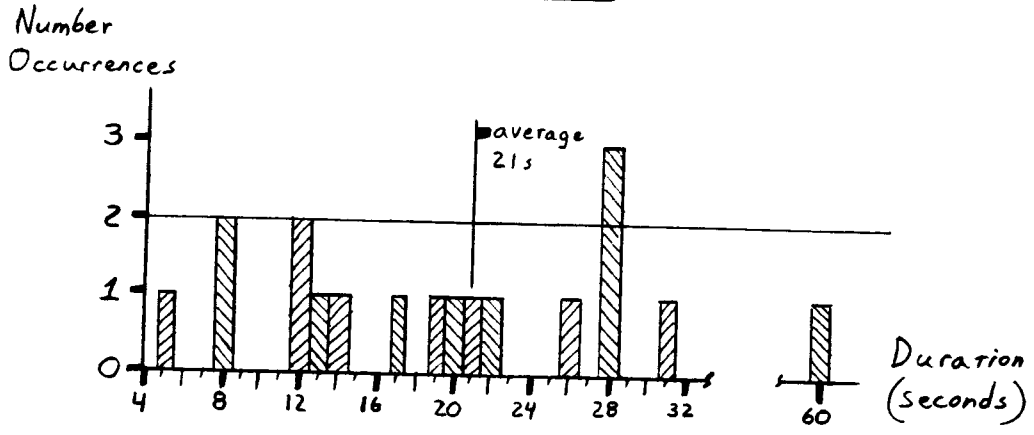
July 9
(1014-1507)



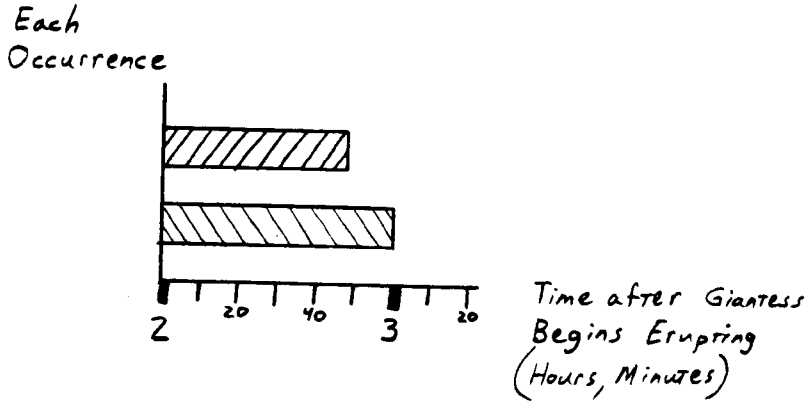
Infant Geyser

July 8 and August 28, 1988

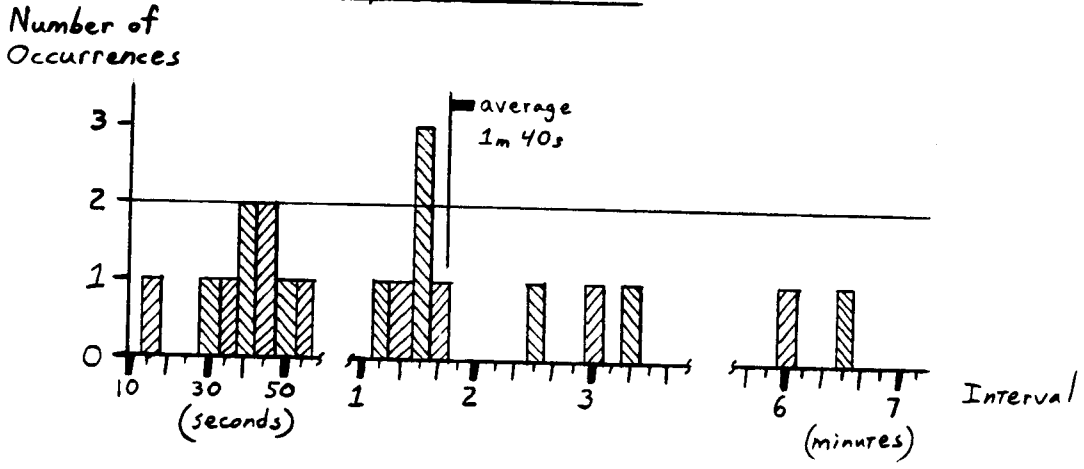
Eruption Duration



Time Between Start of Giantess Eruption and Approximate Start of Infant's Eruptions



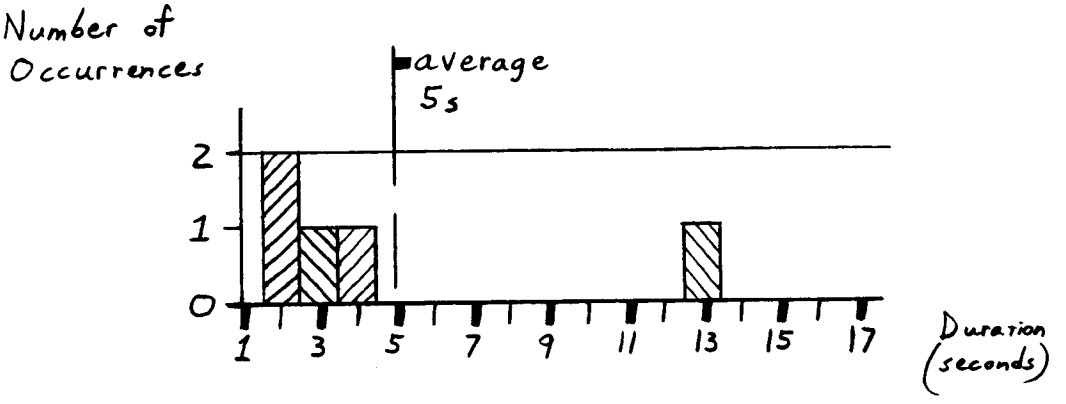
Eruption Interval



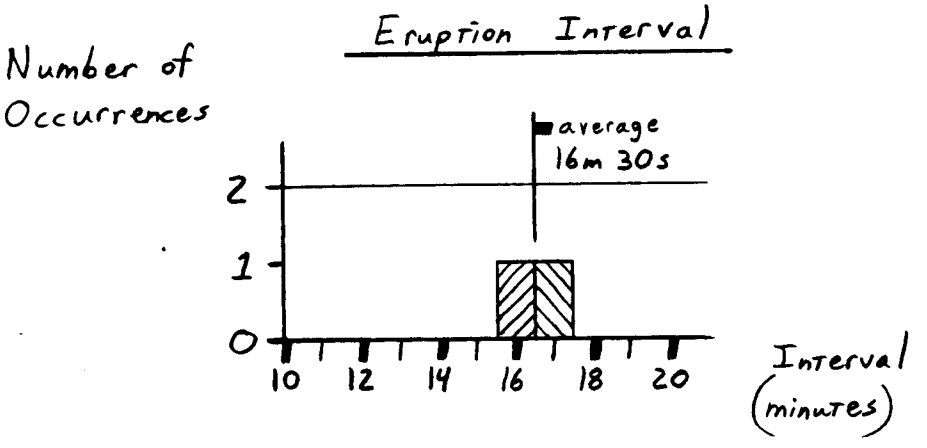
Inverted Geyser

May 1 through October 30, 1988

Eruption Duration



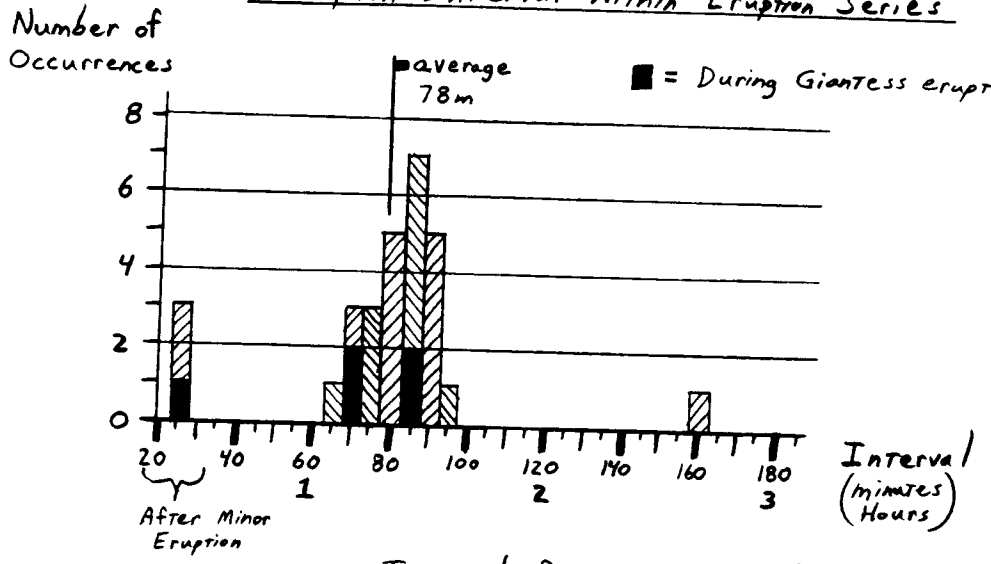
Eruption Interval



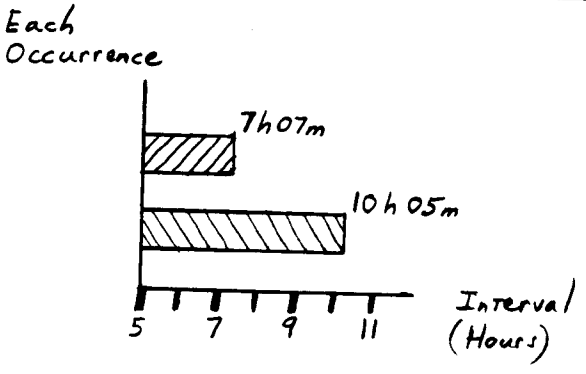
Lion Geyser

April 26 – November 1, 1988

Eruption Interval Within Eruption Series

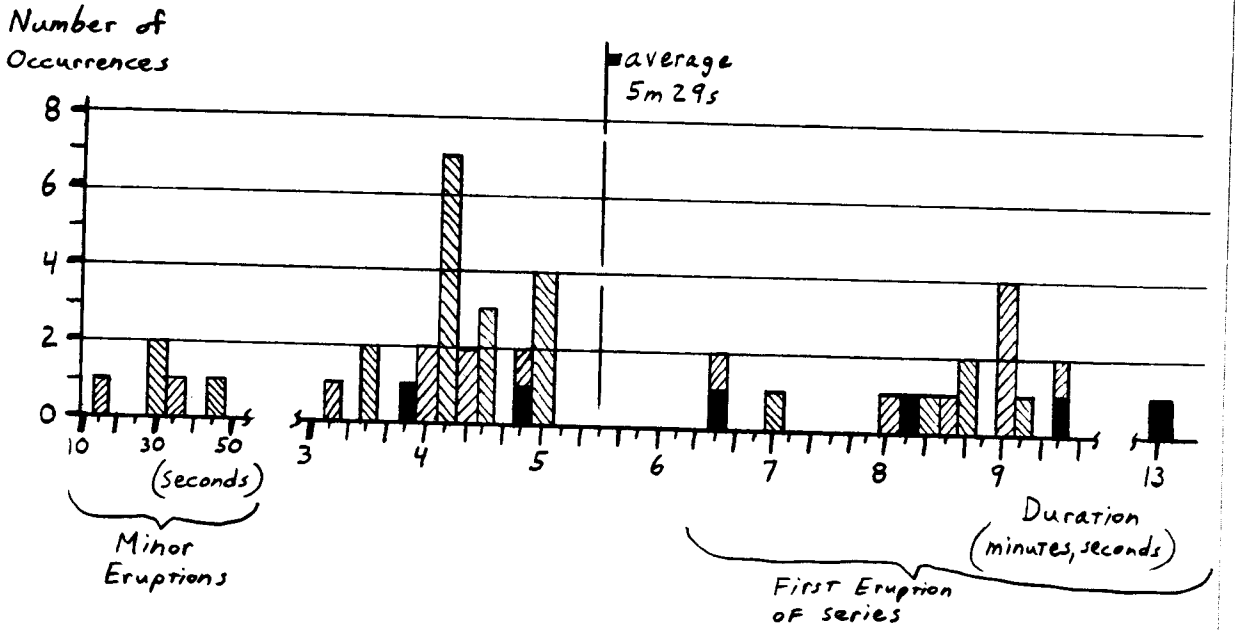


Interval Between Series of Eruptions



Eruption Duration

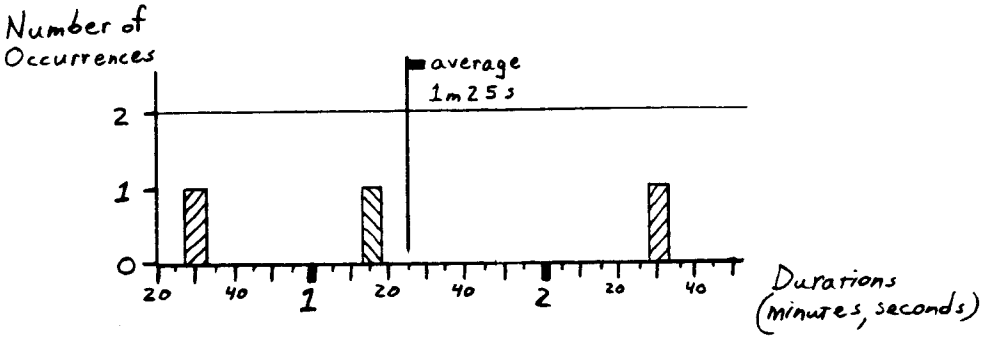
■ = Giantess Active



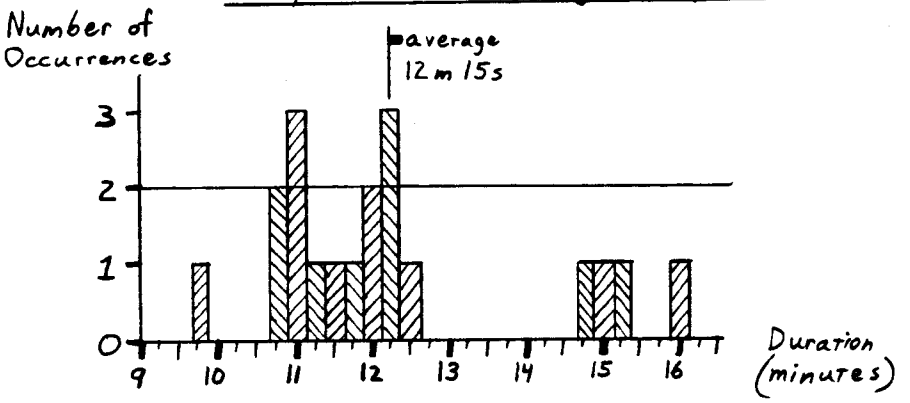
Little Cub Geyser

April 26 - October 30, 1988

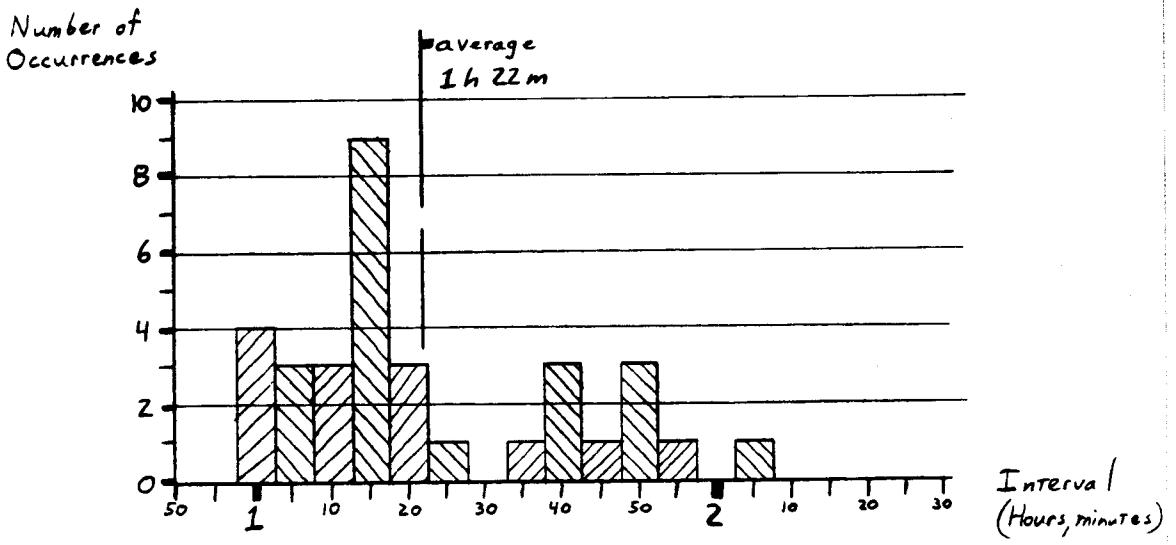
Eruption Duration, Minor Eruptions



Eruption Duration, Major Eruptions



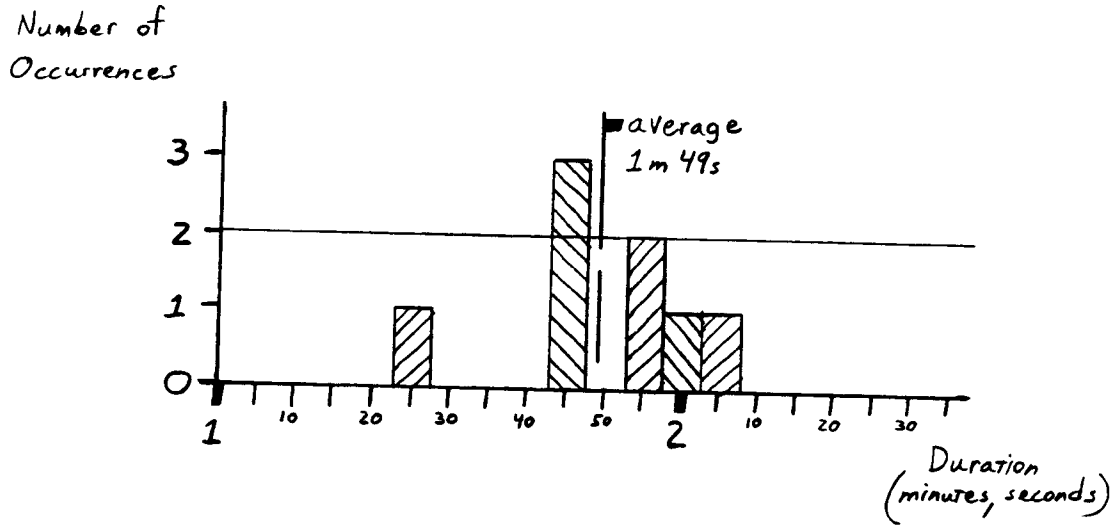
Eruption Interval, Major Eruptions



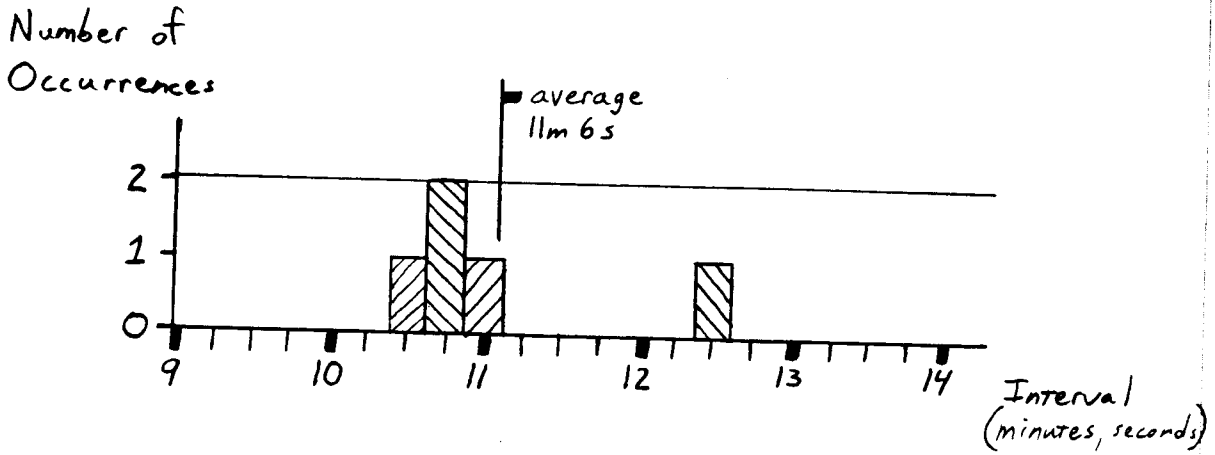
North Goggle Geyser

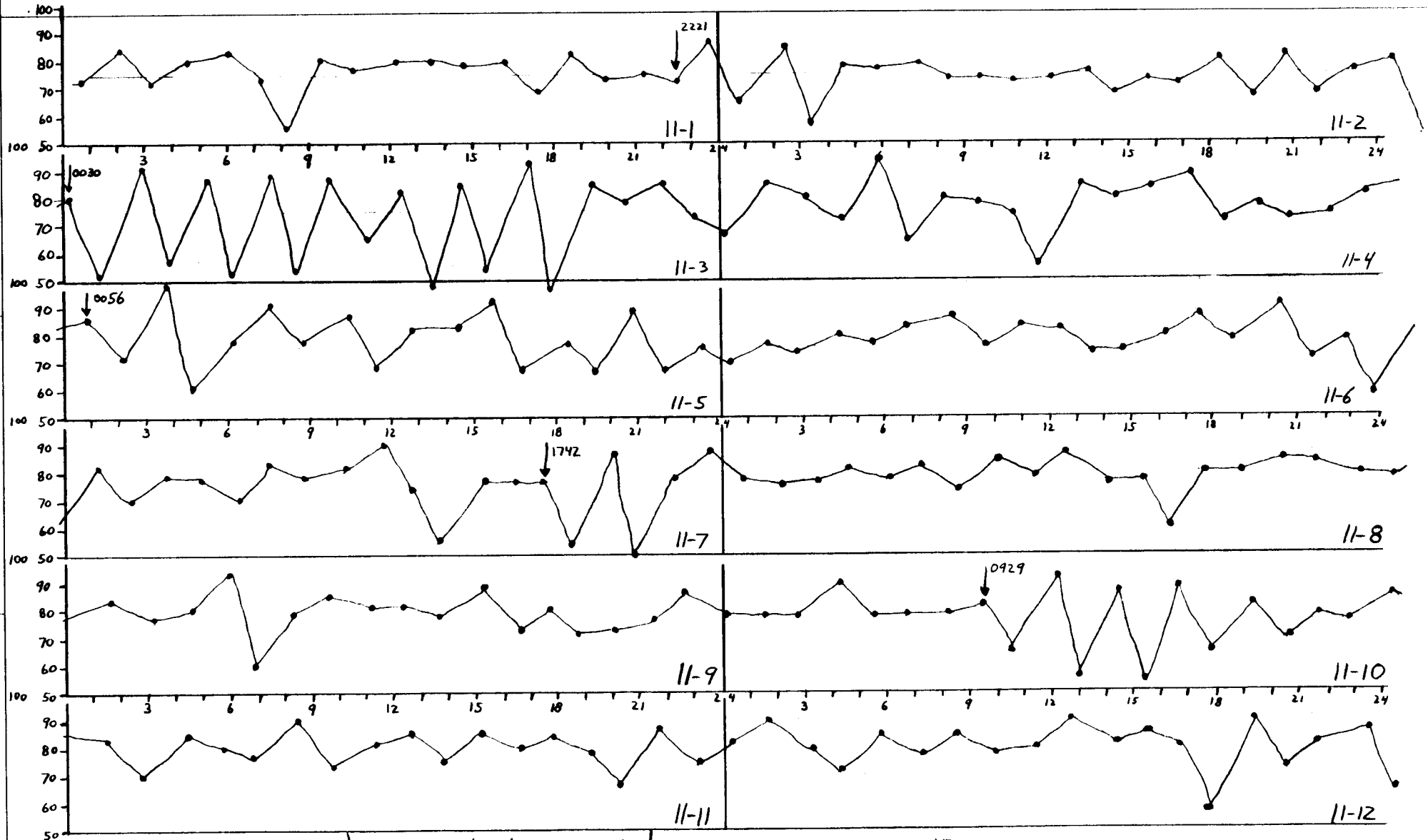
May 1 - August 1, 1988

Duration of Overflow



Interval Between Overflows

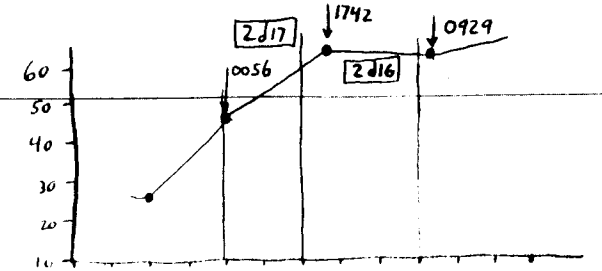


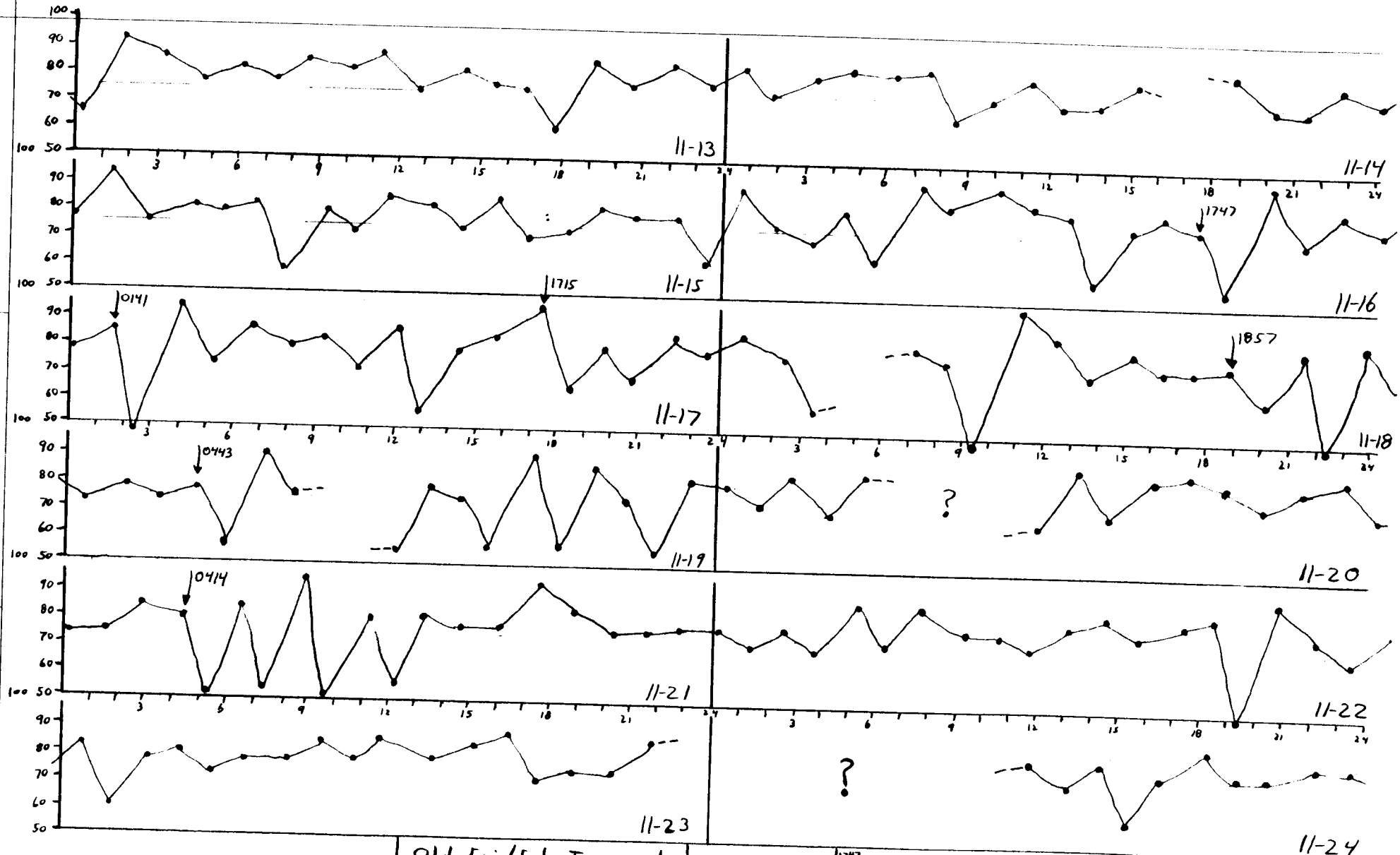


Old Faithful Intervals
November 1-12, 1987

Intervals (Hours)

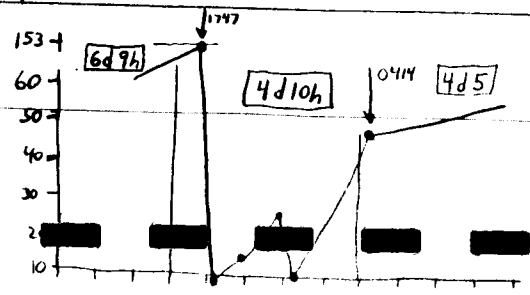
26 64
48
65

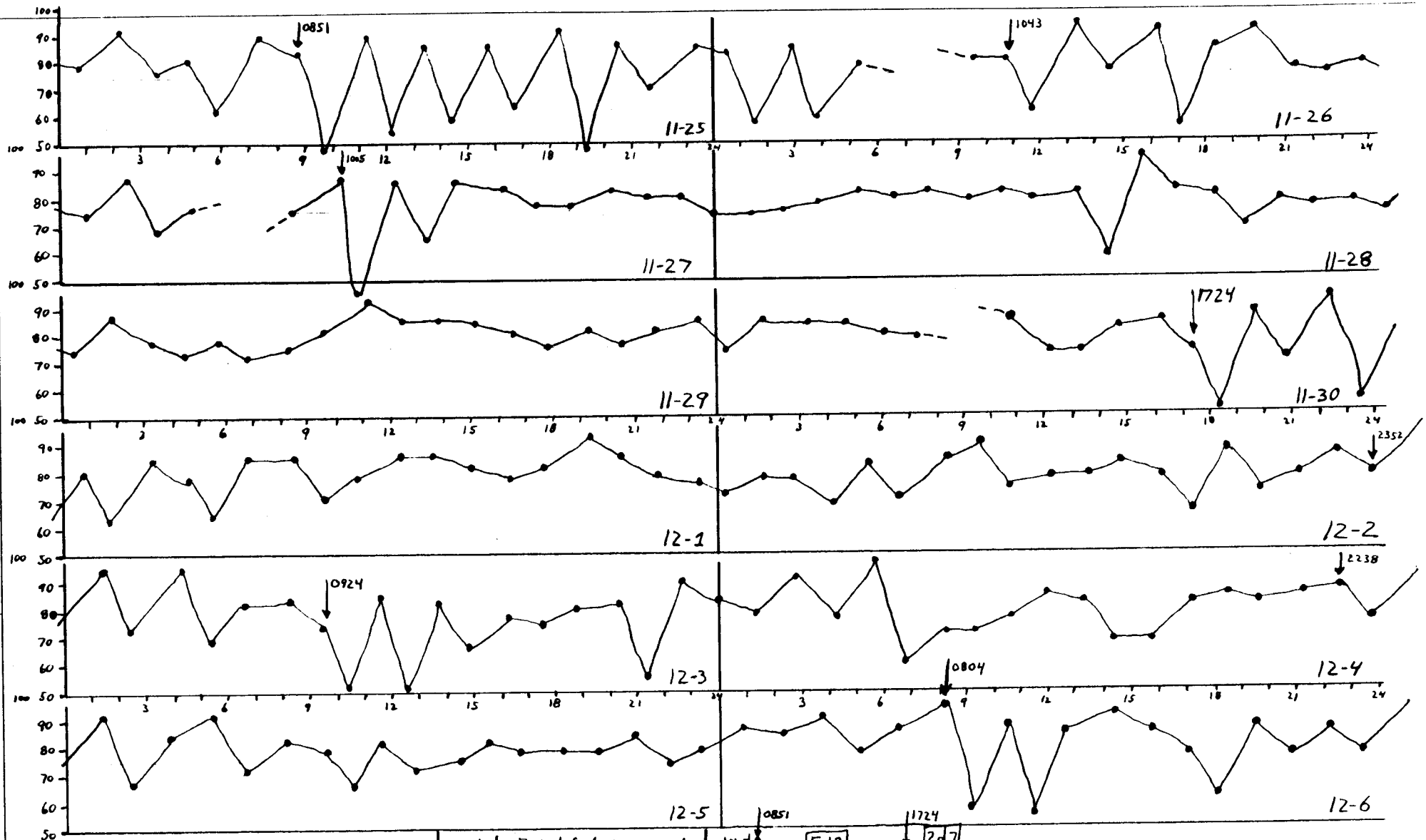




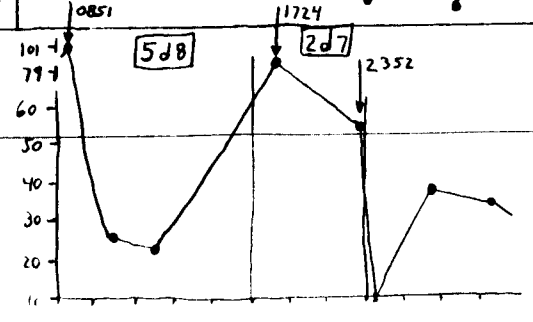
Old Faithful Intervals
November 13-24, 1987

Intervals (Hours)	
153	10
8	47
26	

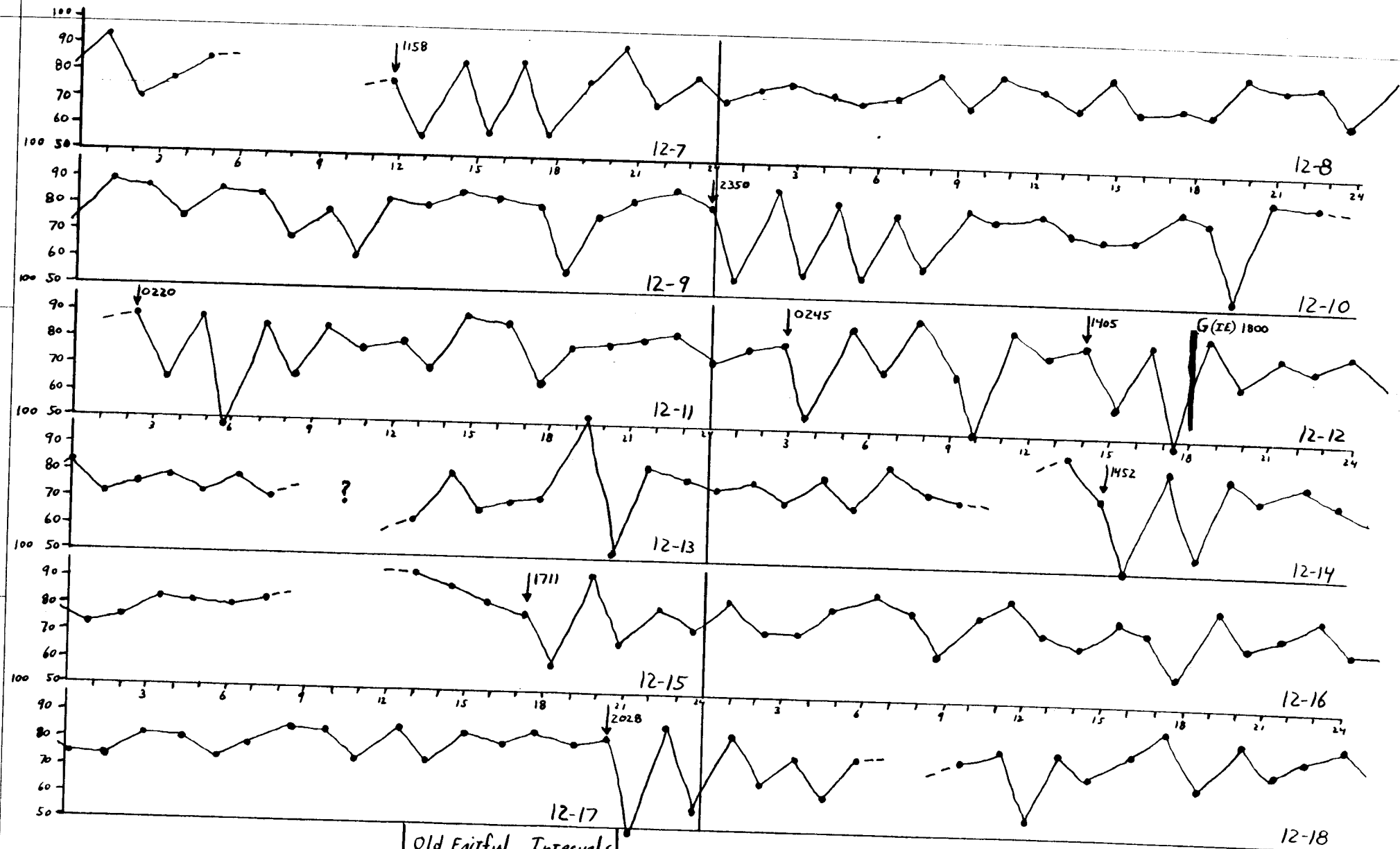




Old Faithful Intervals
Nov. 25 - Dec. 6, 1987



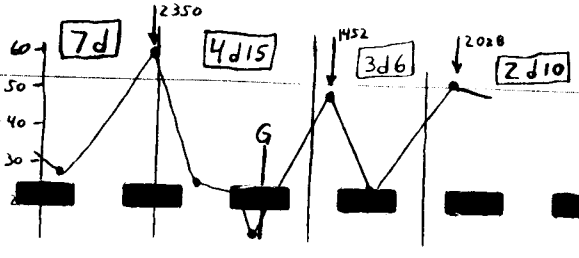
Intervals (Hours)	
62	55
26	9
23	37
79	

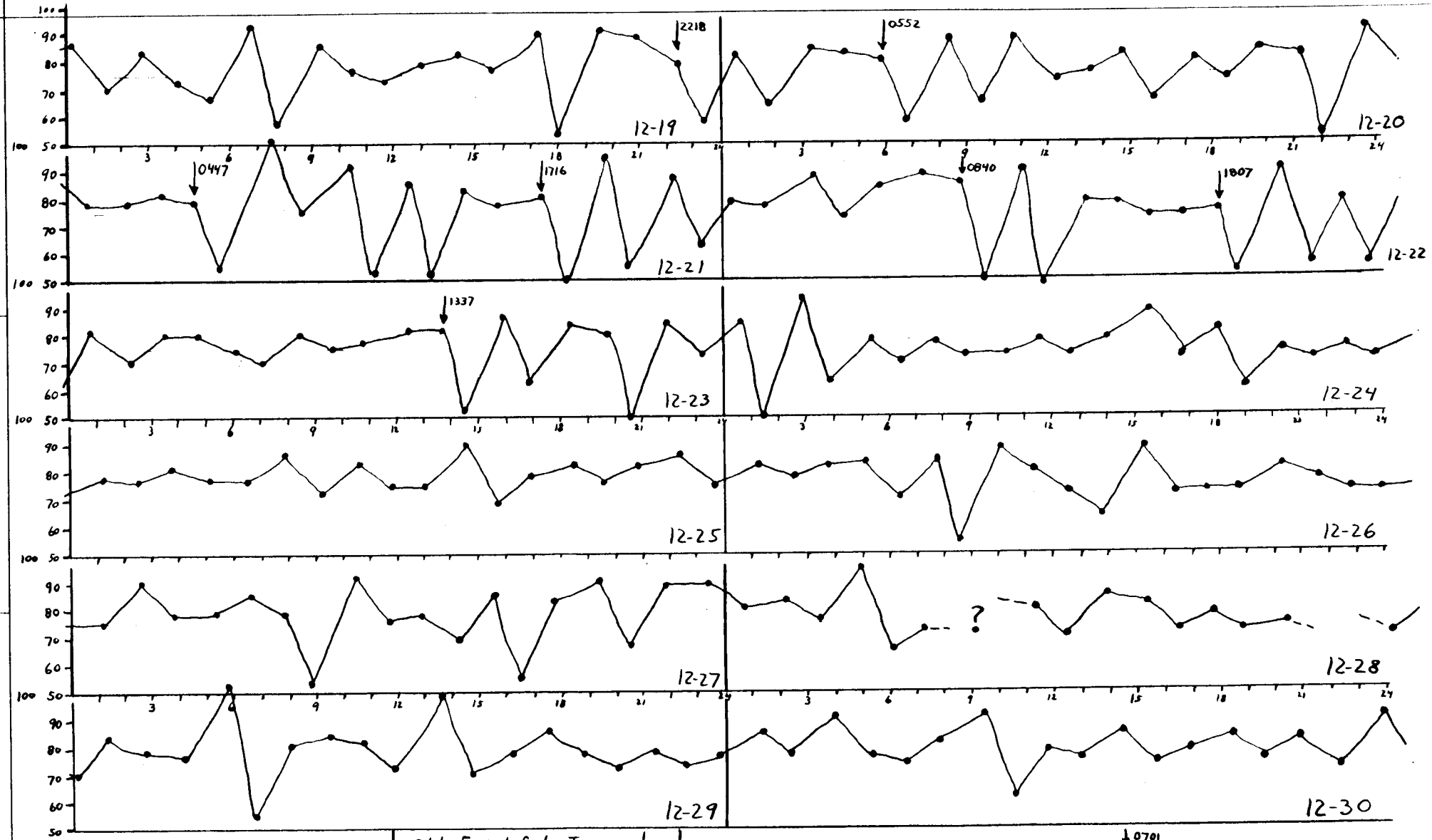


Old Faithful Intervals
December 7-18, 1987

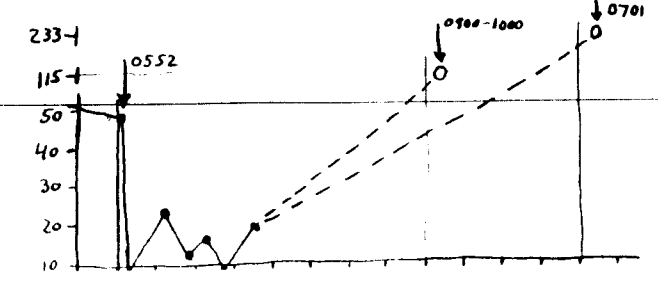
Intervals (Hours)

28	11
60	49
26	26
	51



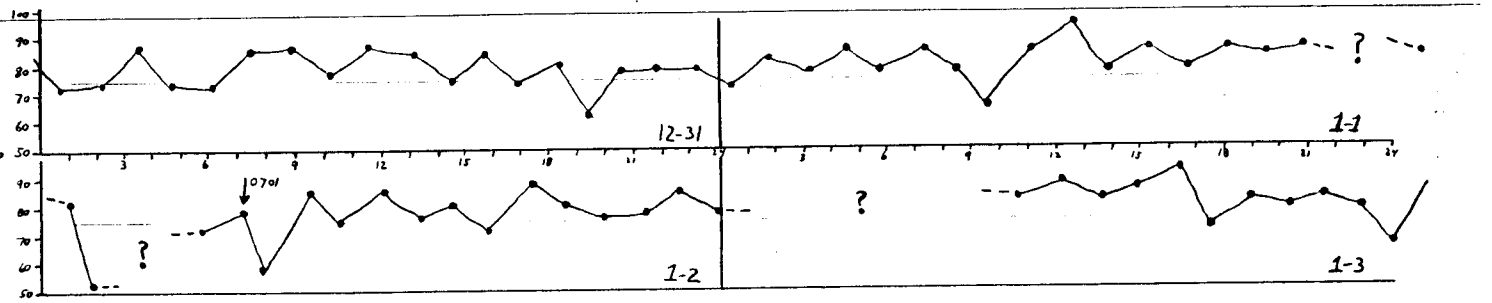


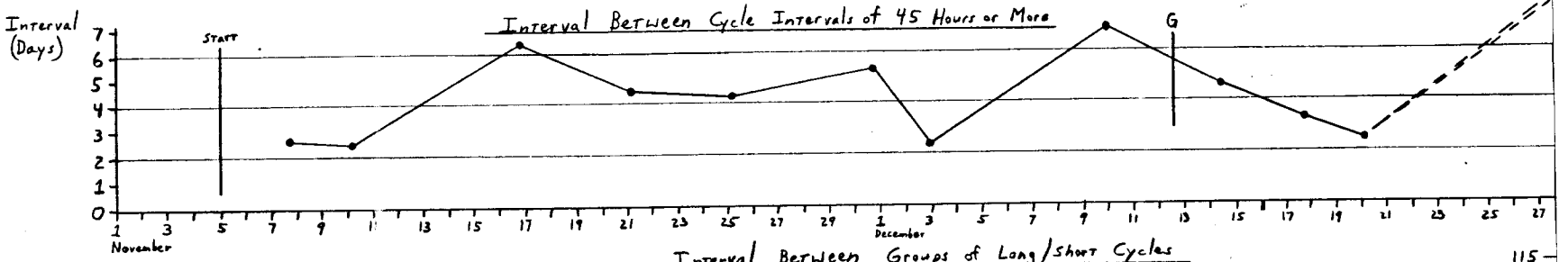
Old Faithful Intervals
December 19-30, 1987

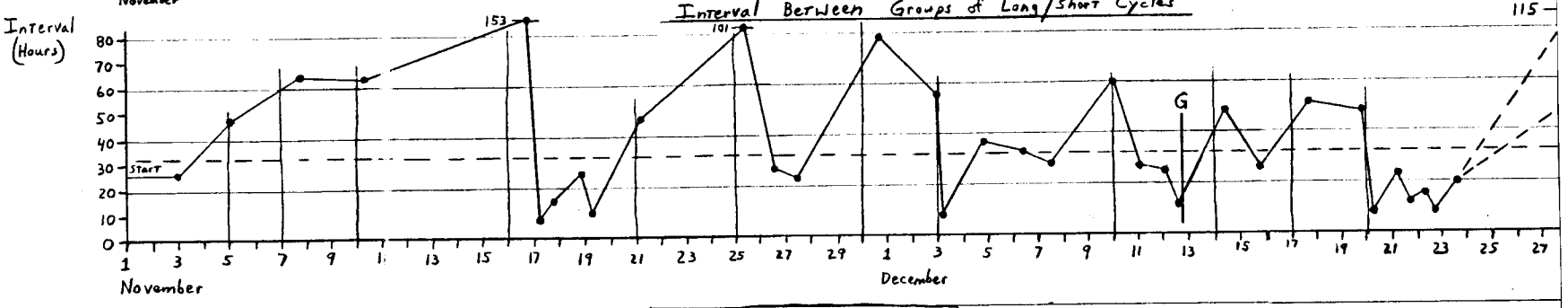


Intervals (Hours)

48	12	115 (4d19)
8	15	OR 233 (9d17)
23	9	

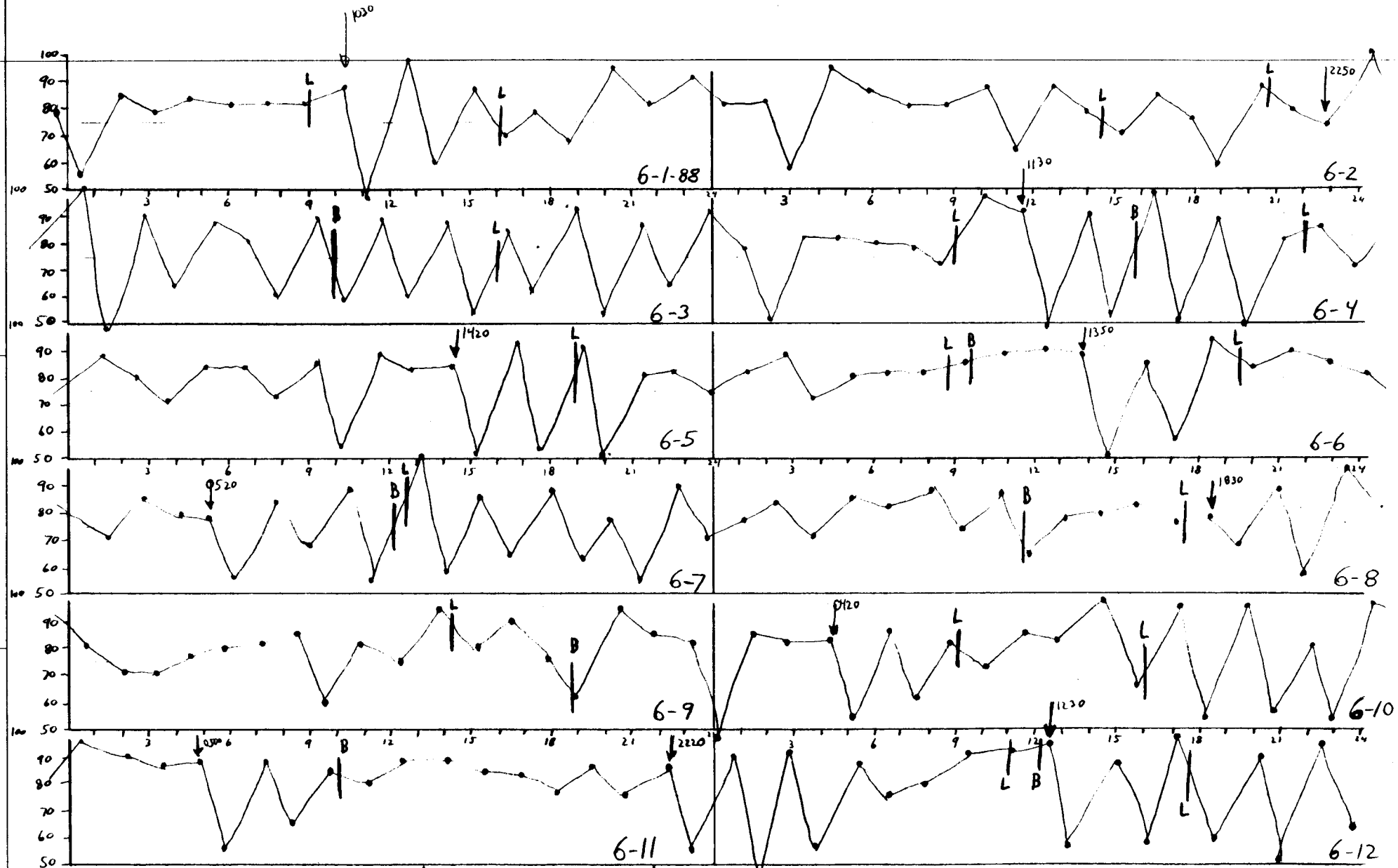






Old Faithful Intervals
Dec. 31, 1987 - Jan. 3, 1988

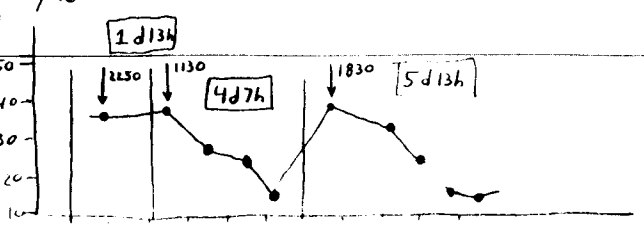
248

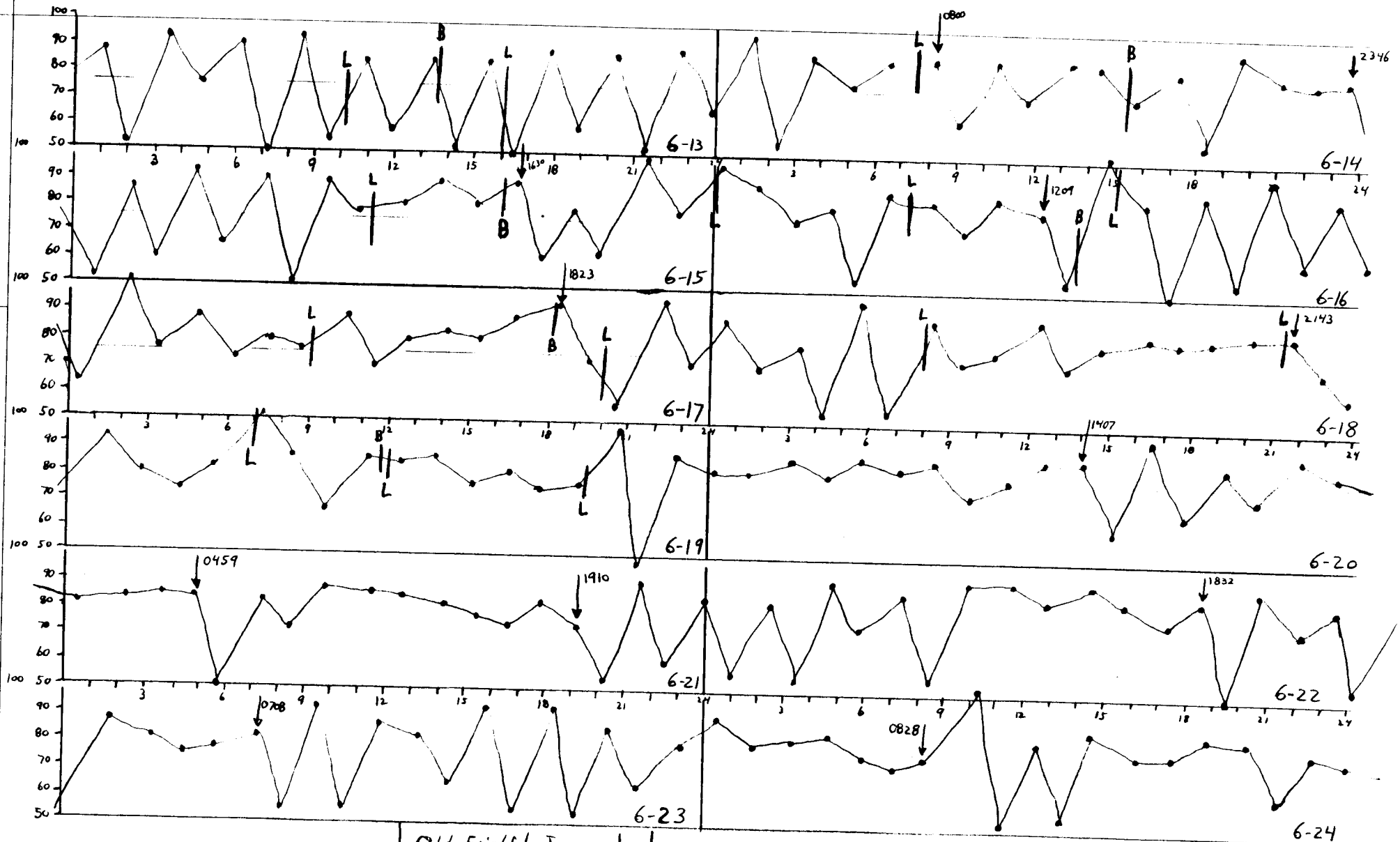


Old Faithful Intervals
June 1-12, 1988

Intervals (Hours)		
36	15	25
37	37	17
27	34	14
24		

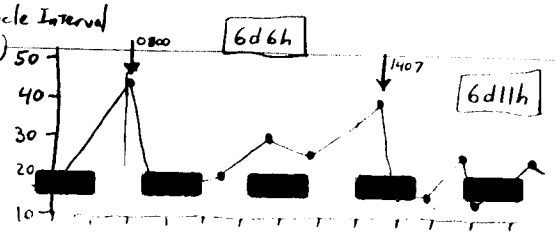
Long-short cycle

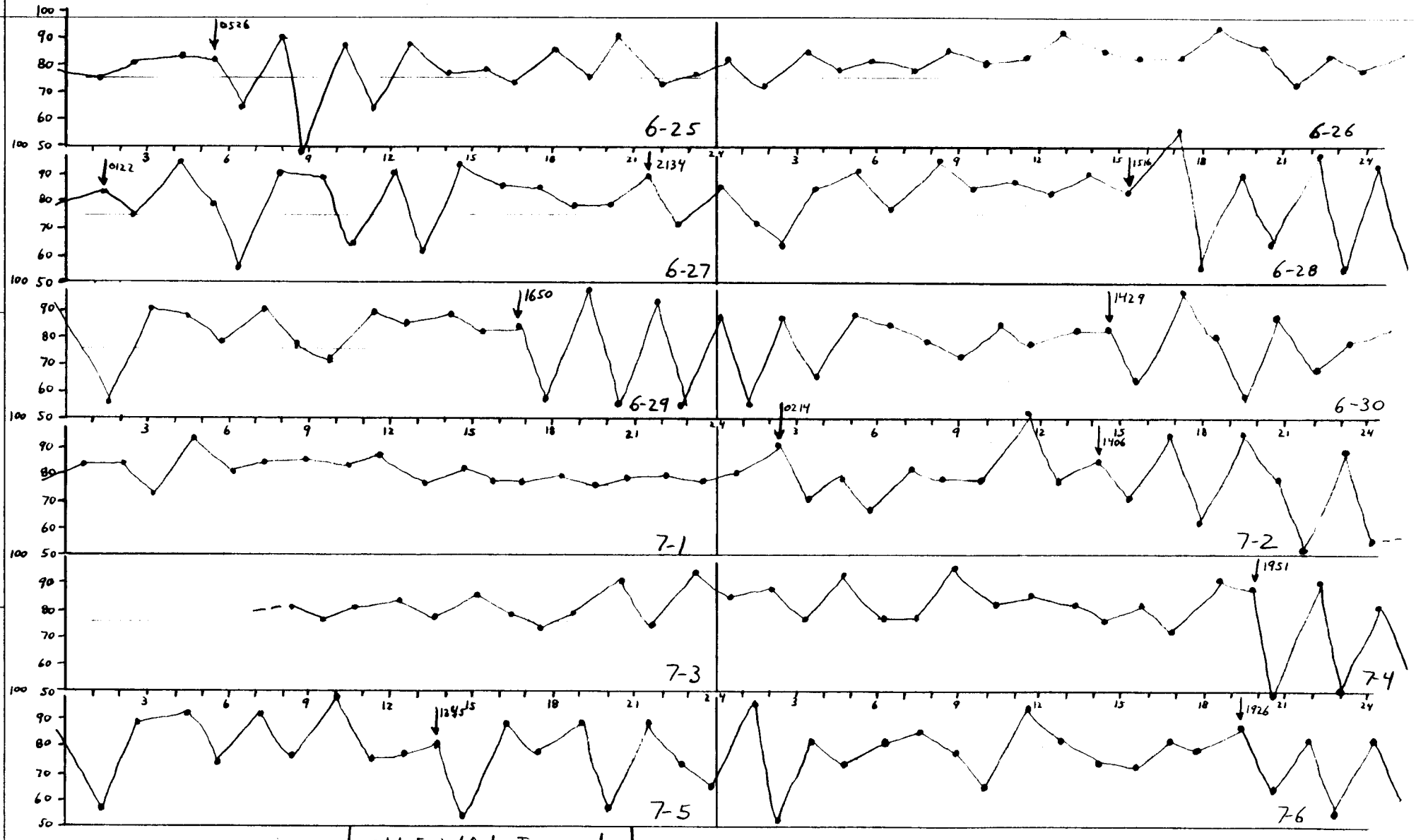




Old Faithful Intervals
June 13-24, 1988

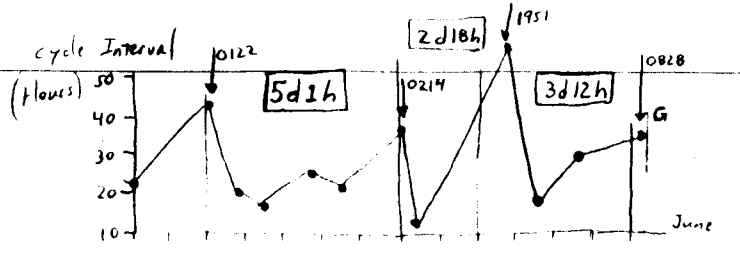
Interval (Hours)			
	44	30	24
	16	27	12
	17	40	25
	20	5	
		14	

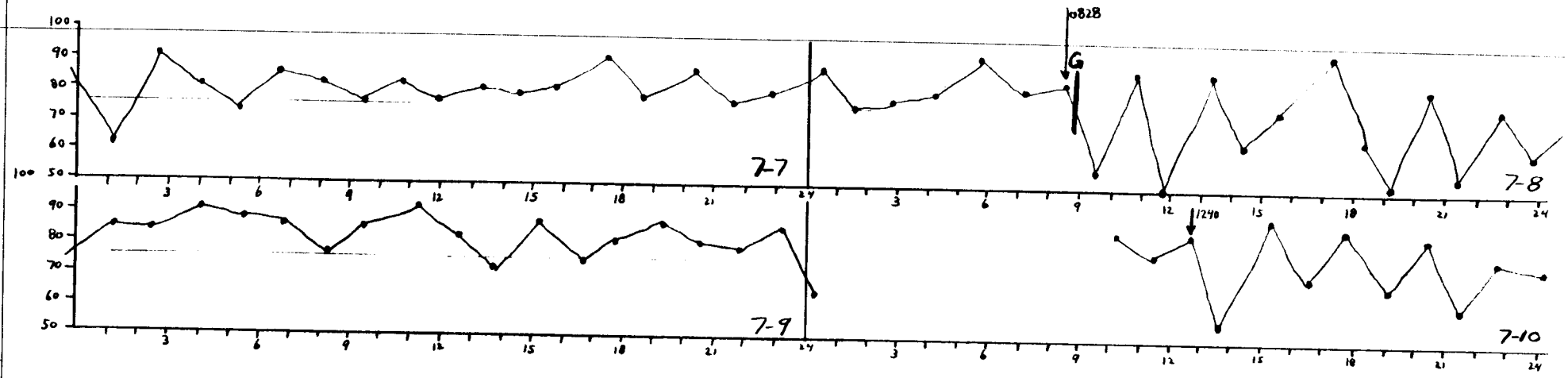


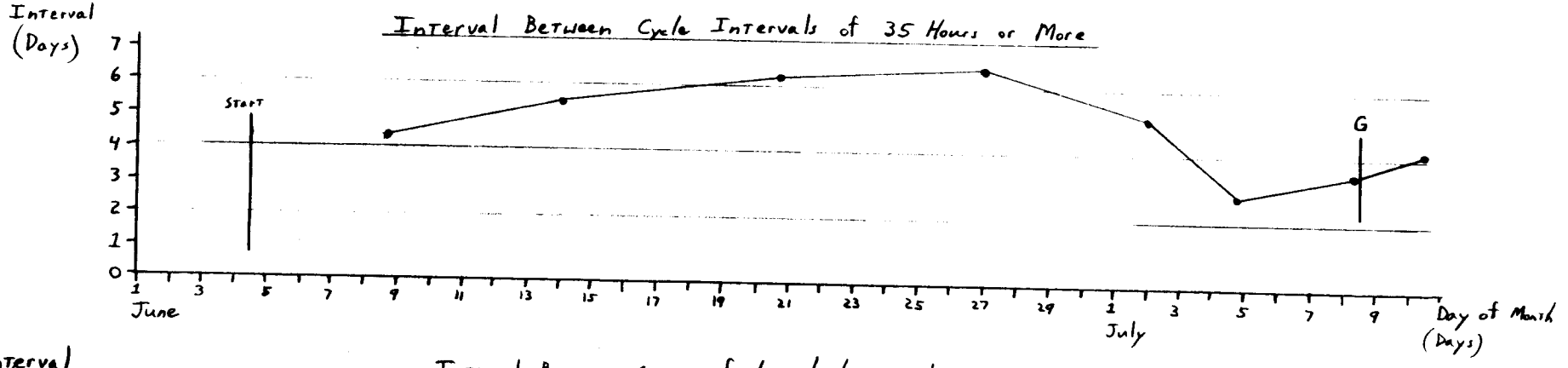


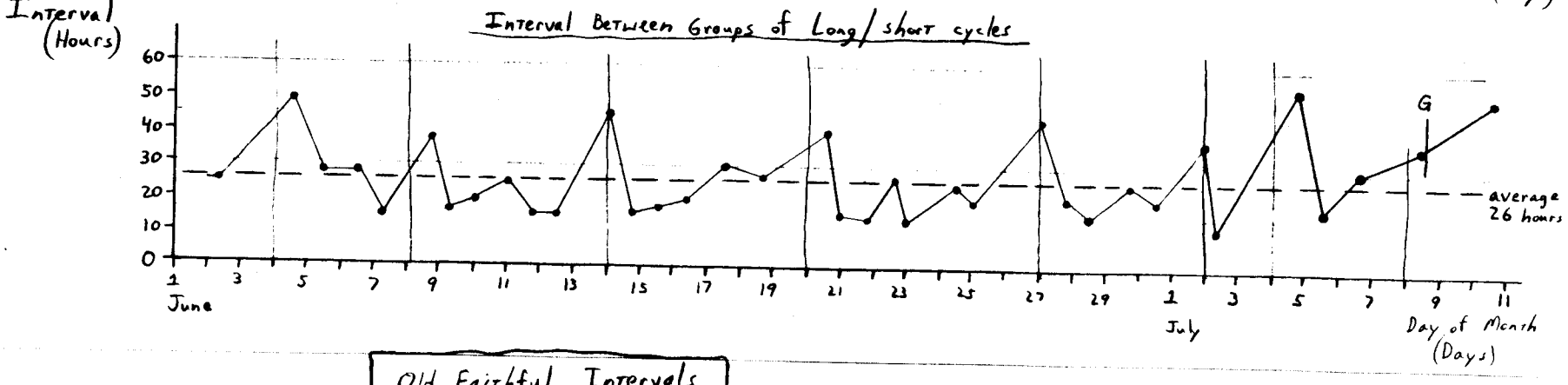
Old Faithful Intervals
June 25 - July 6, 1988

Interval (Hours)			
	21	26	54
	44	21	18
	20	36	30
	18	12	37









Old Faithful Intervals
July 7-10, 1988

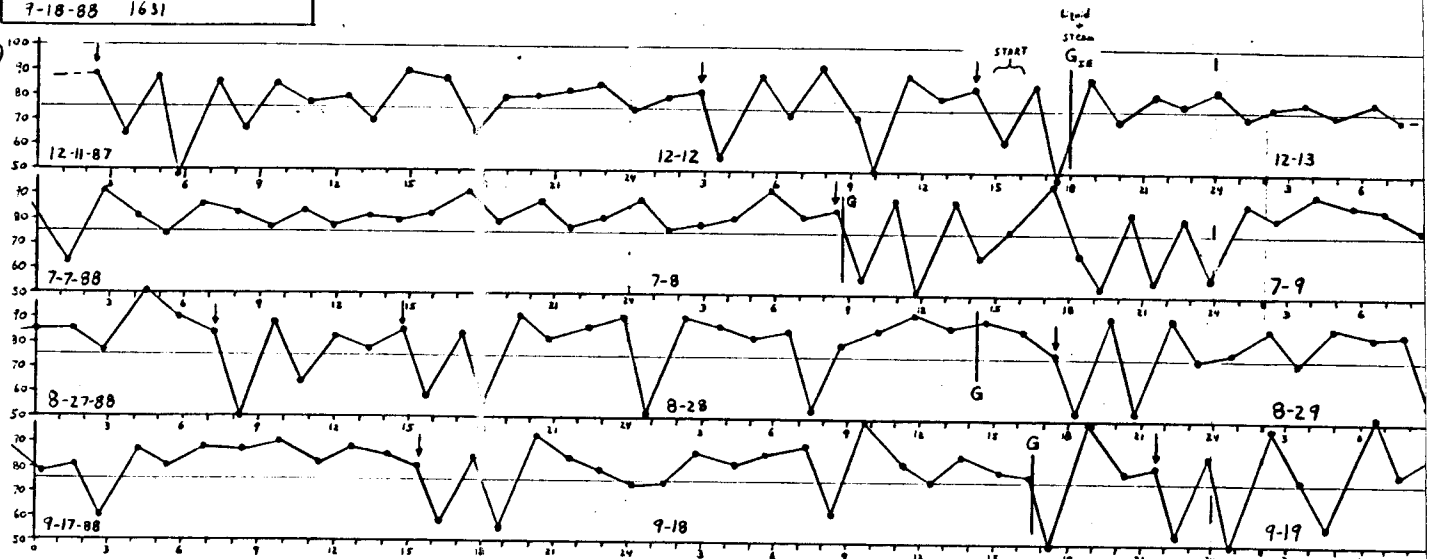
Old Faithful Intervals and Giantess Eruptions

● = Old Faithful Eruption

G = Giantess Eruption

↓ = start of Old Faithful Interval Oscillations

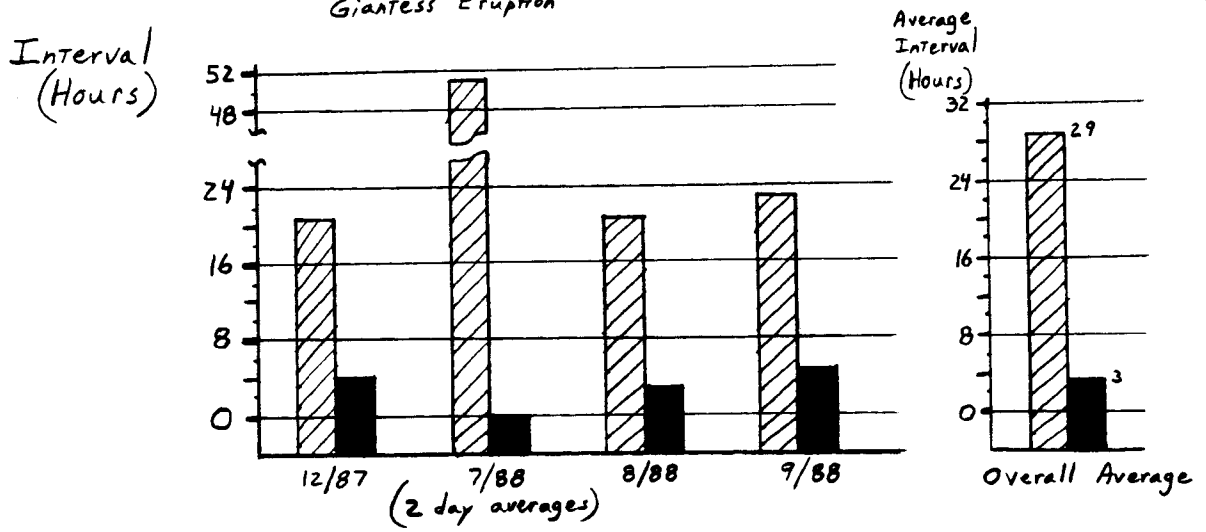
Giantess Eruptions Graphed	
12-12-87	1800_{LE} (steam + Liquid)
7-8-88	0858
8-28-88	1418
9-18-88	1631



Old Faithful and Giantess (Data collected within ± 2 days of Giantess eruption)

▨ ≡ Interval Between Periods of old Faithful Oscillations

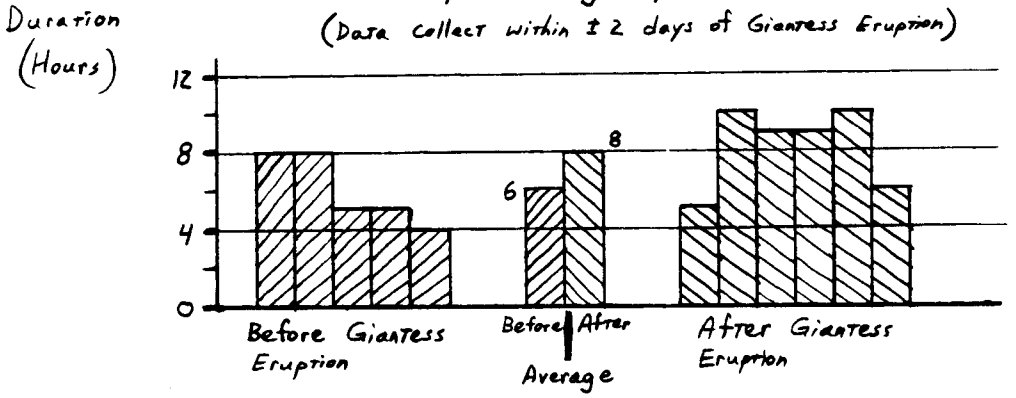
■ ≡ Time between old Faithful Oscillation start and Giantess Eruption



Durations of Old Faithful Interval Oscillations

12/87 through 9/88

(Data collect within ± 2 days of Giantess Eruption)



Interval Between Periods of old Faithful Oscillations

12/87 through 9/88

(Data Collected within ± 2 days of Giantess Eruption)

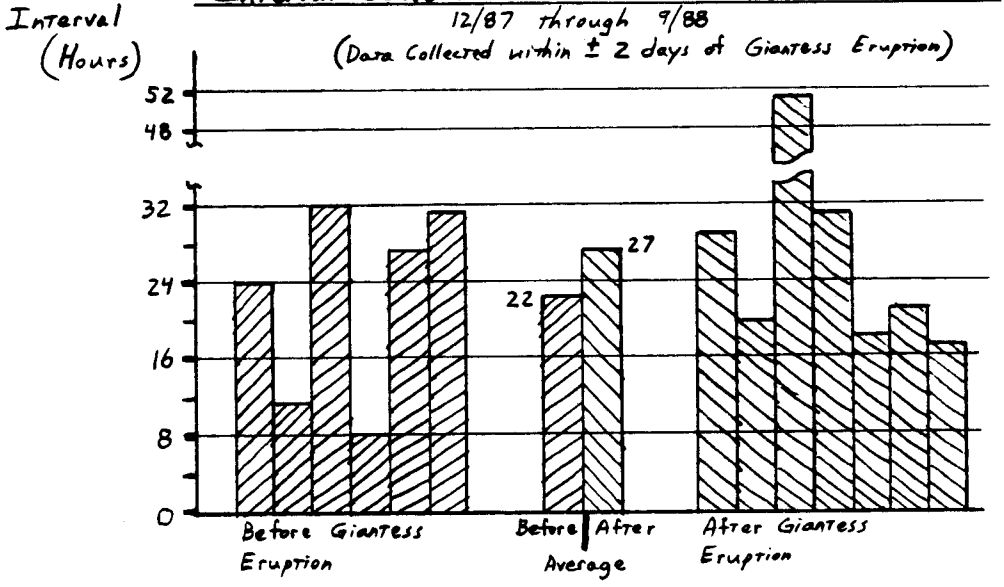
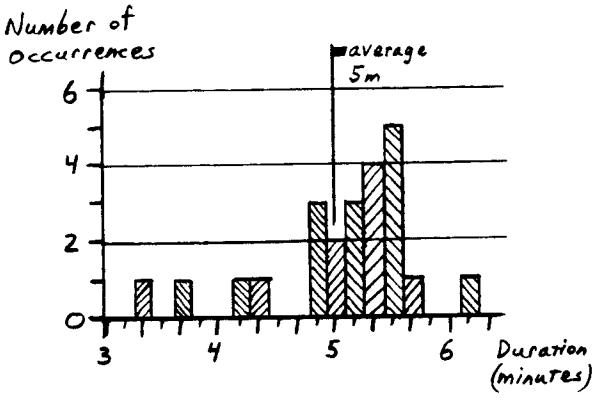


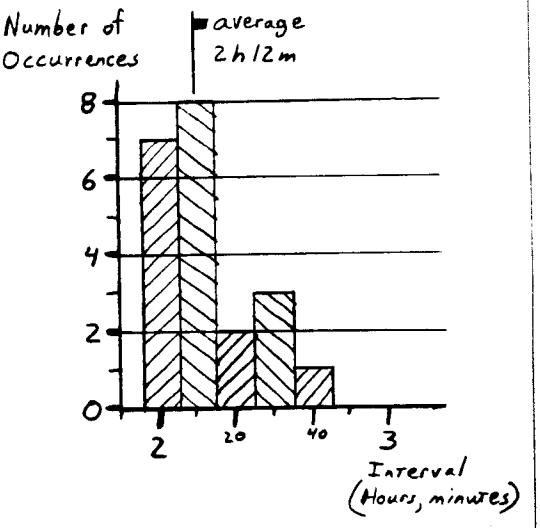
Plate Geyser

April 26 - November 1, 1988

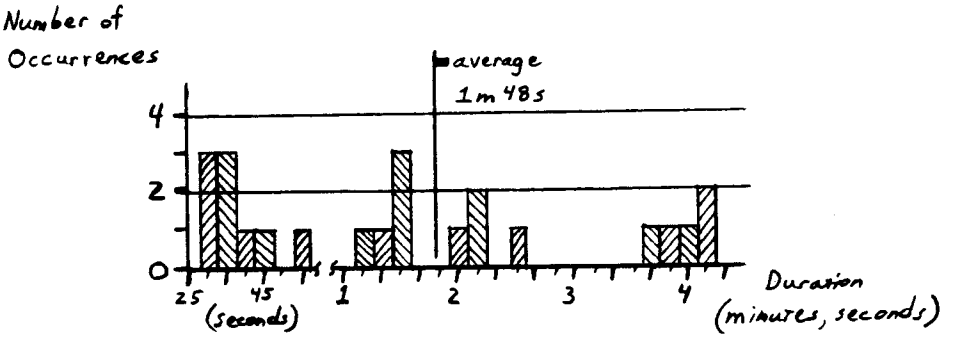
Eruption Duration



Eruption Interval



Eruption Duration, Giantess Active



Eruption Interval, Giantess Active

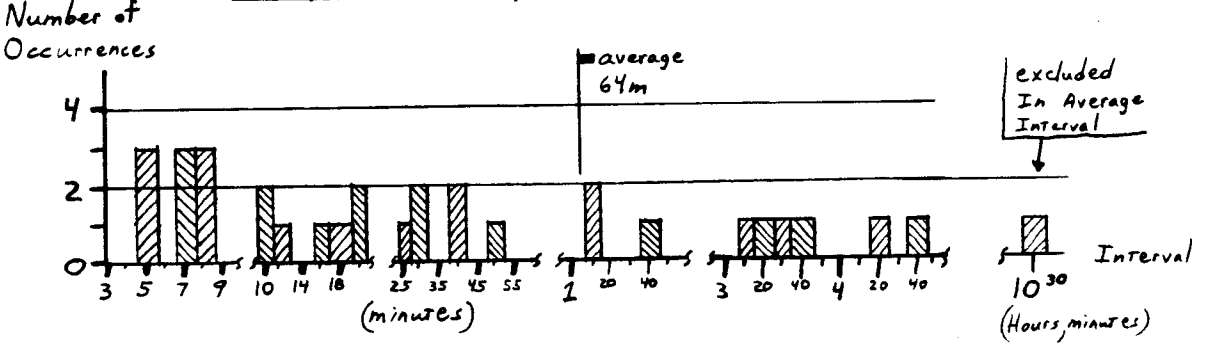
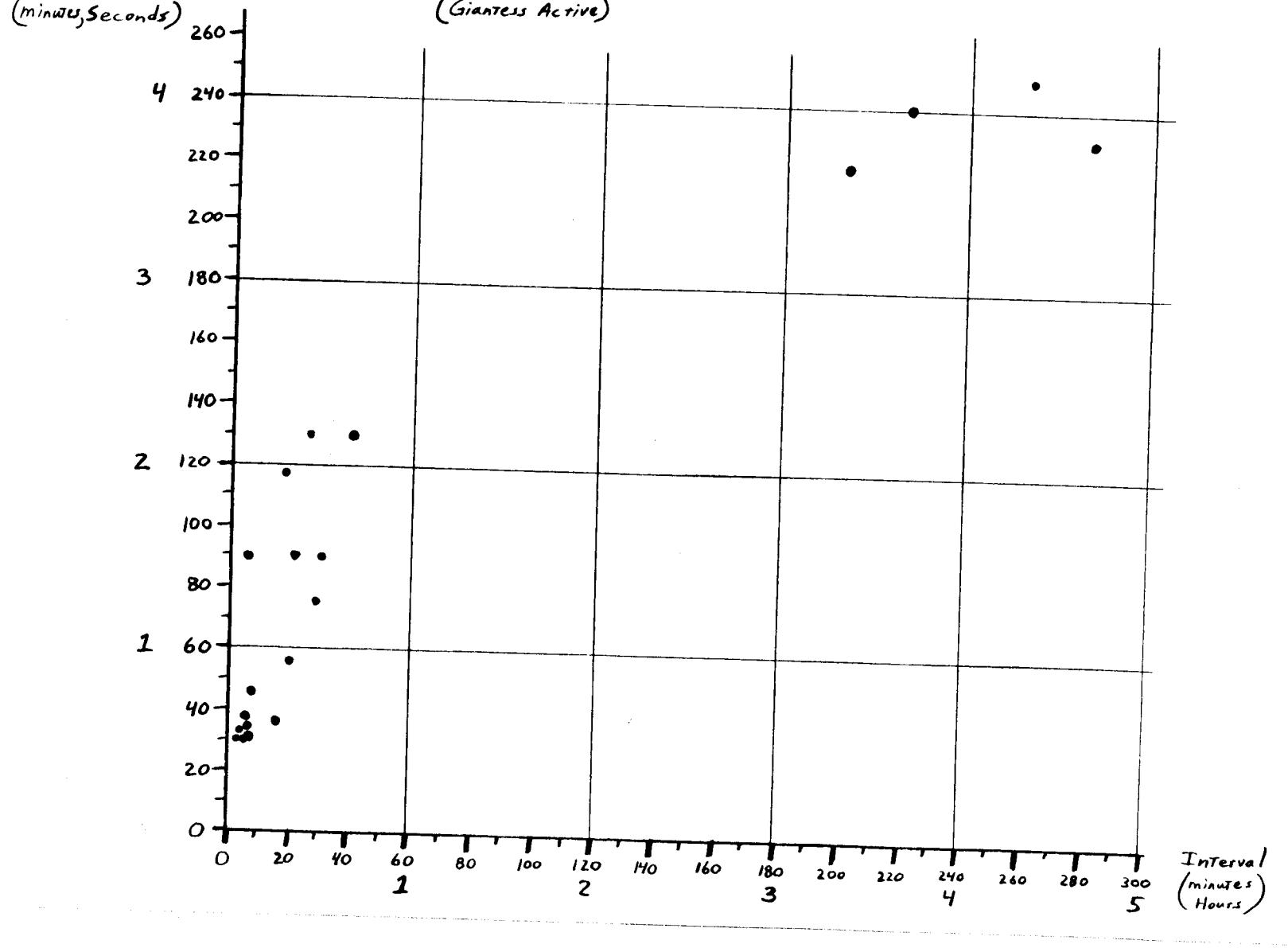


Plate Geyser

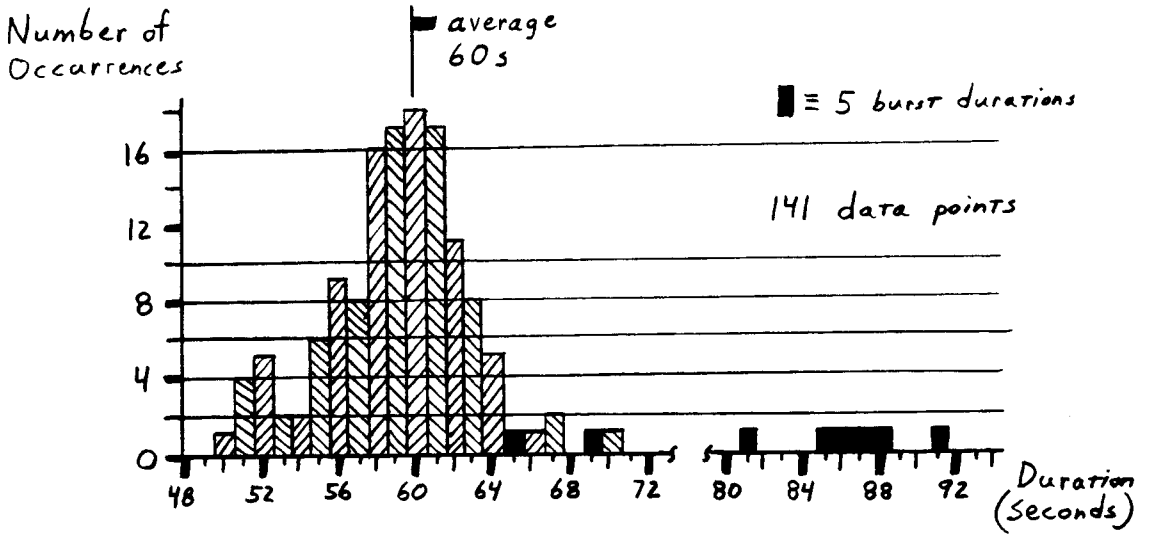
July 8 + August 28, 1988
(Giantess Active)



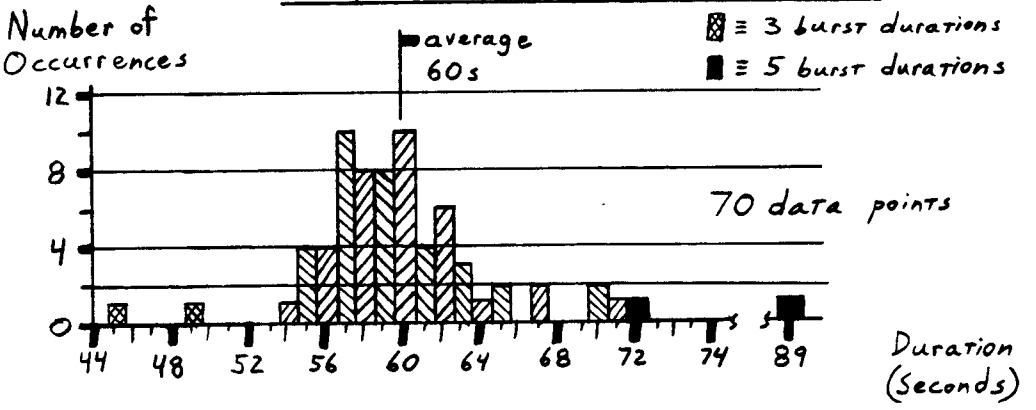
Plume Geyser

April 26 - October 31, 1988

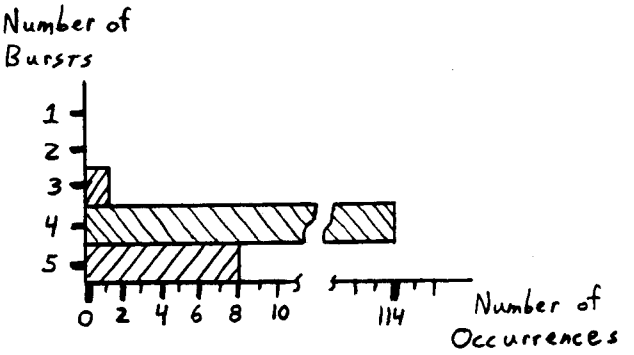
Eruption Duration



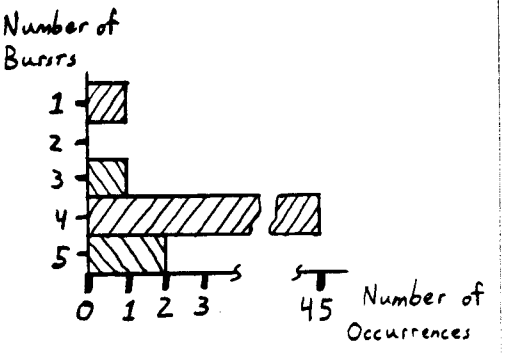
Eruption Duration (Giantess Active)



Number of Bursts Per Eruption



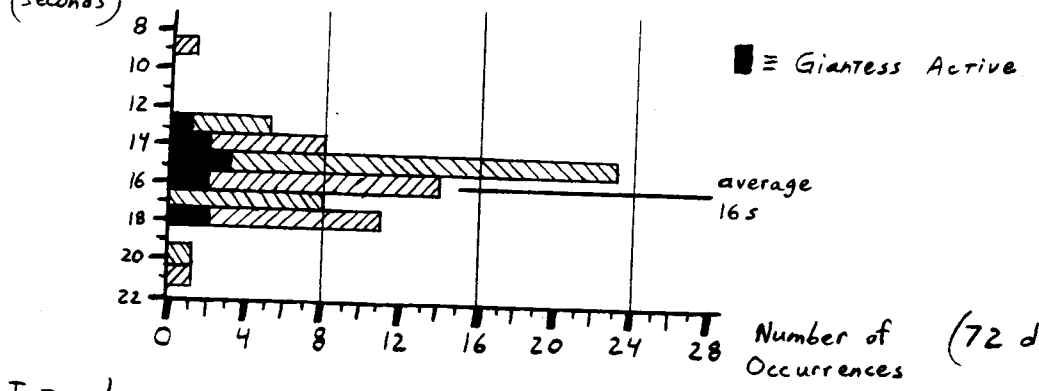
Number of Bursts Per Eruption (Giantess Active)



Plume Geyser

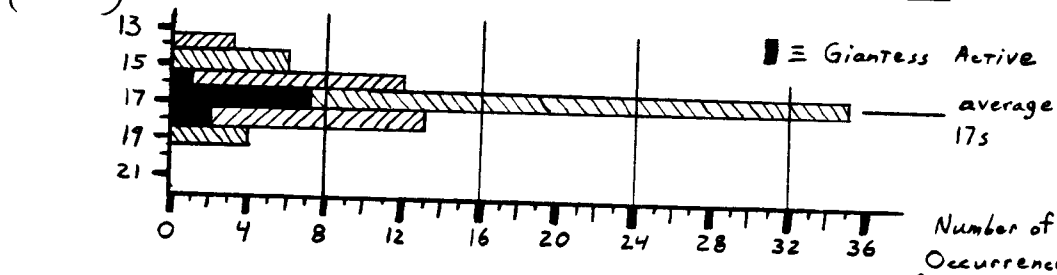
May 10 - October 31, 1988

Interval Between First and Second Bursts



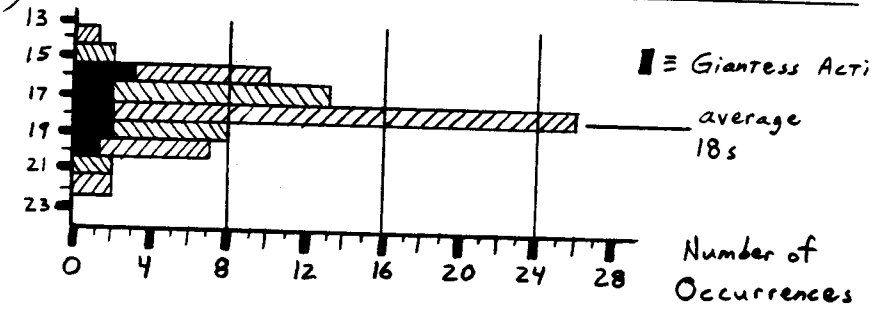
(72 data points)

Interval Between Second and Third Bursts



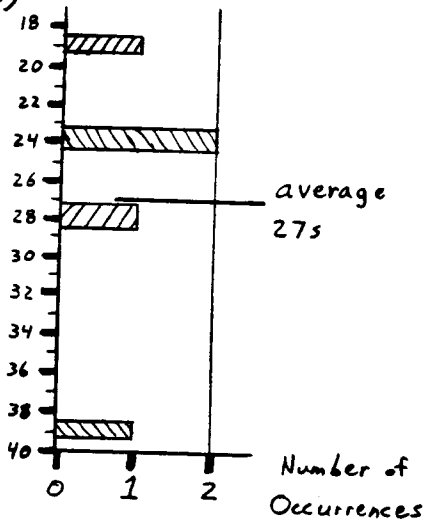
(73 data points)

Interval Between Third and Fourth Bursts



(71 data points)

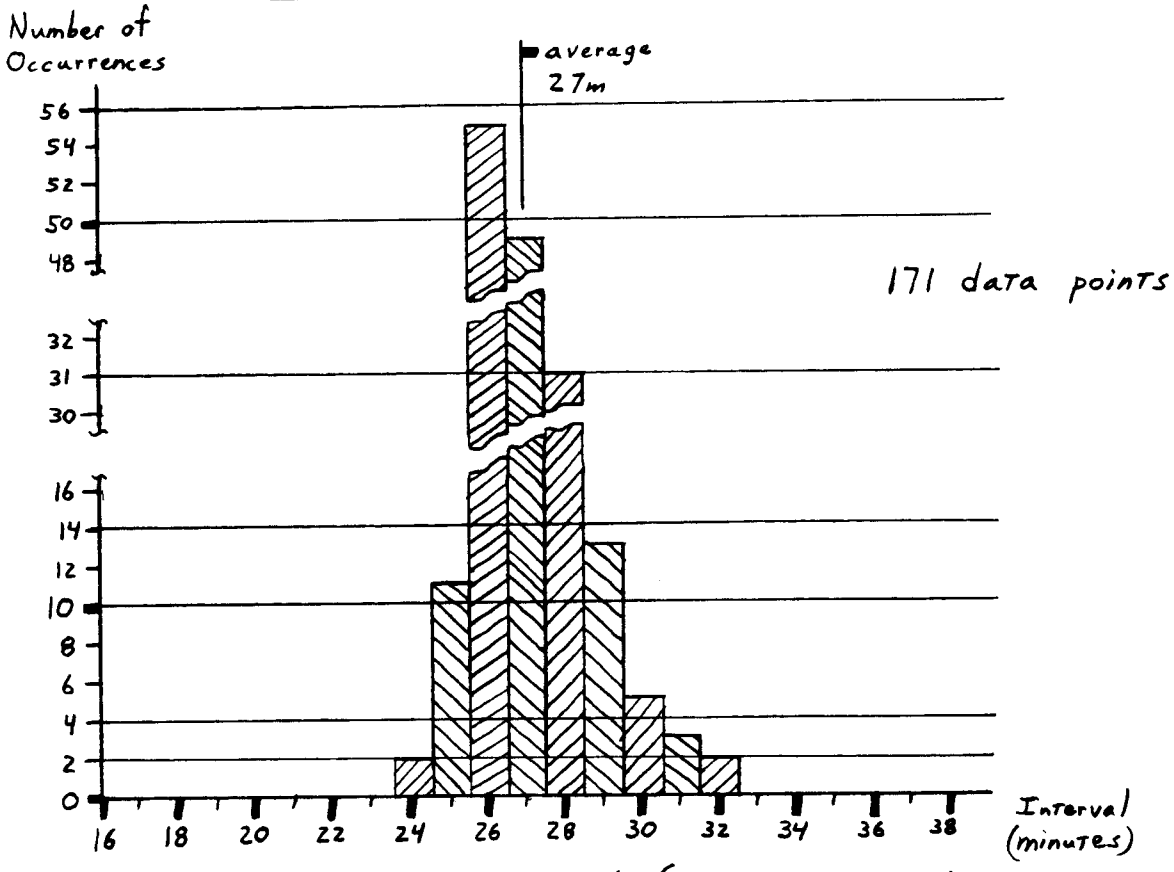
Interval Between Fourth and Fifth Bursts



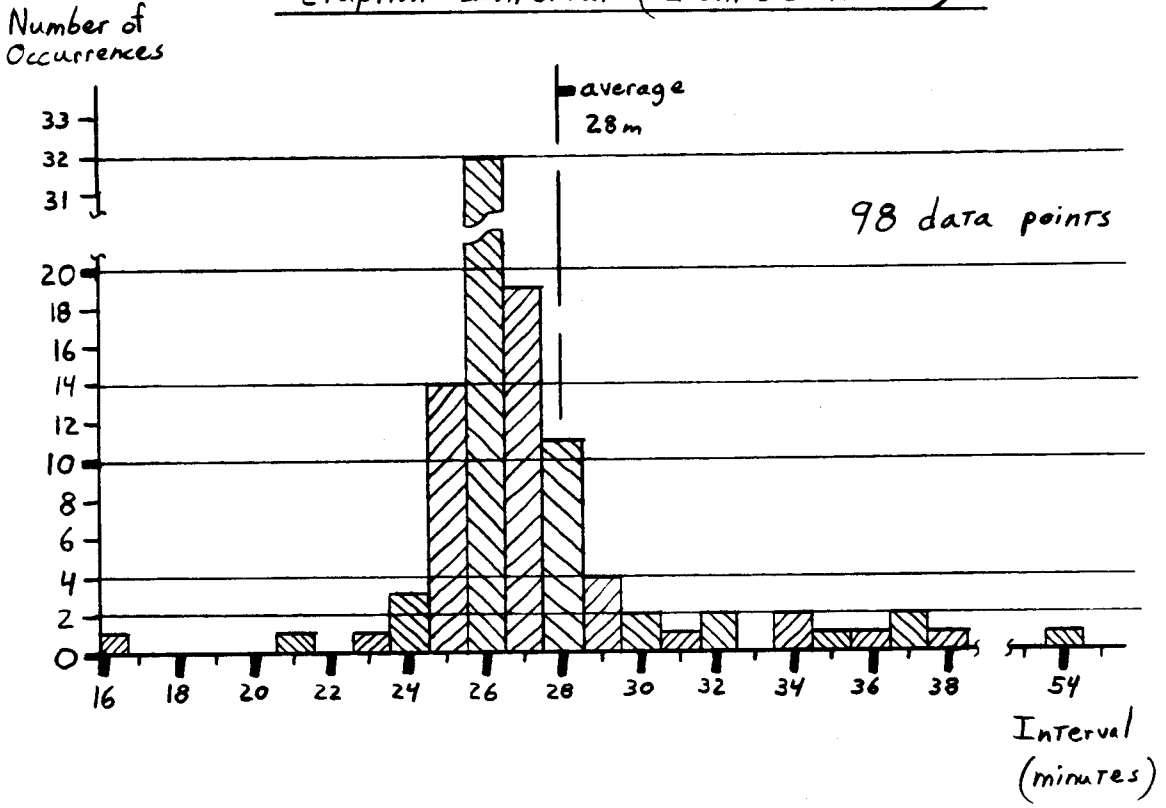
Plume Geyser

April 26 - October 31, 1988

Eruption Interval



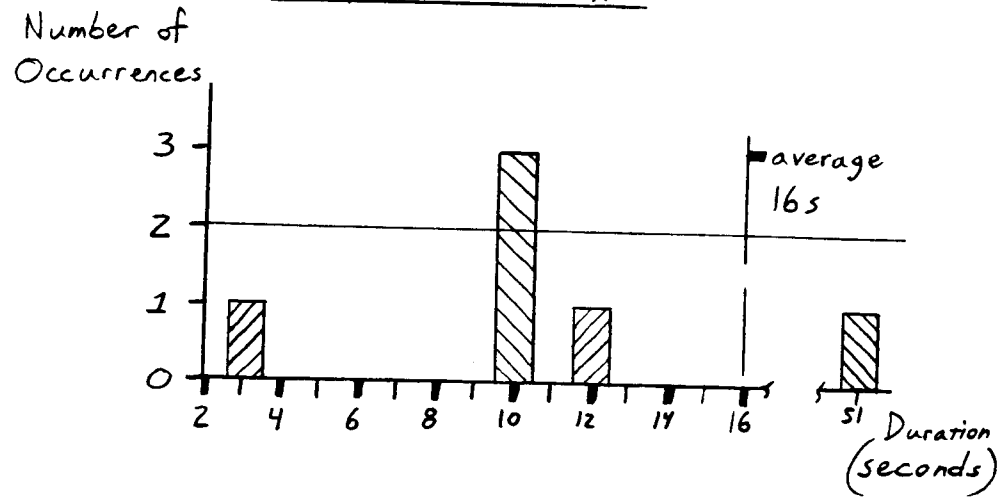
Eruption Interval (Giantess Active)



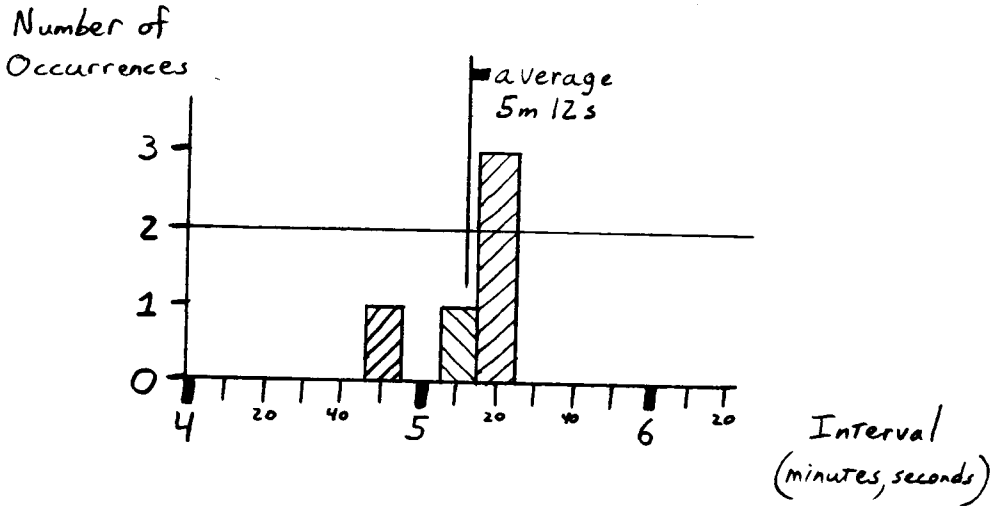
Solitary Geyser

May 14, 1988

Eruption Duration



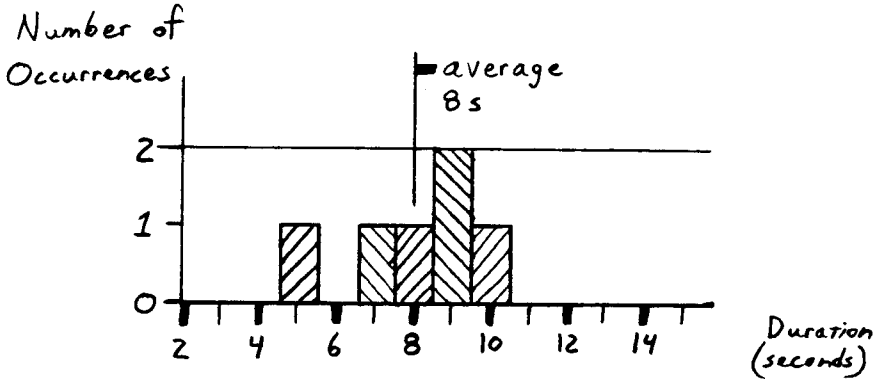
Eruption Interval



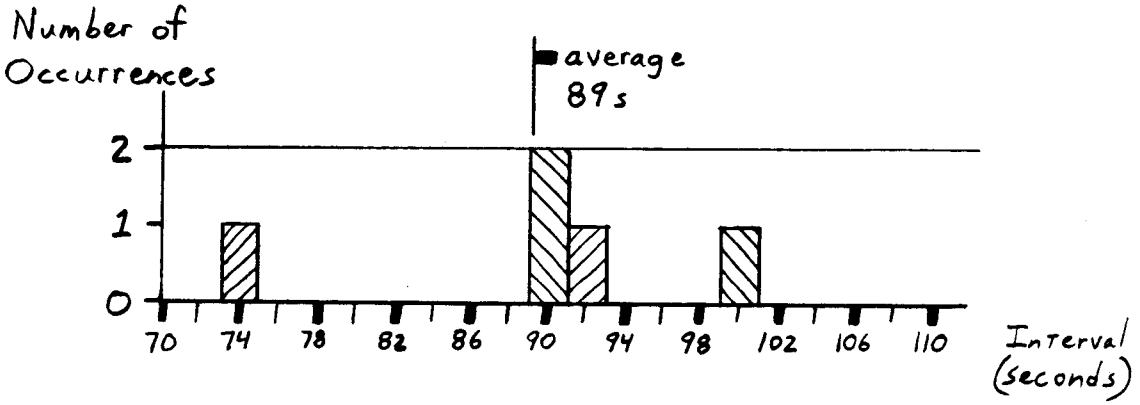
Sponge Geyser

June 3, 1988

Eruption Duration



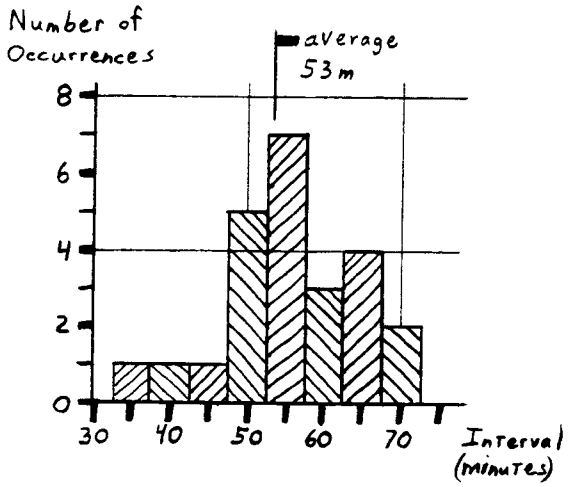
Eruption Interval



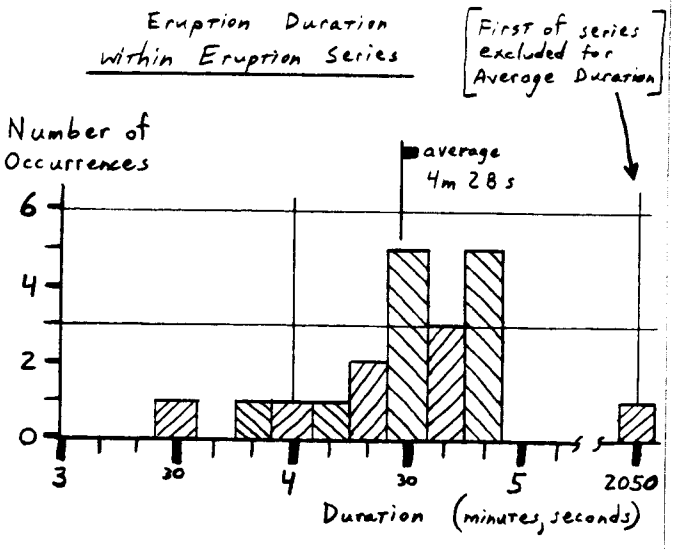
Vault Geyser

April 26 - October 31, 1988

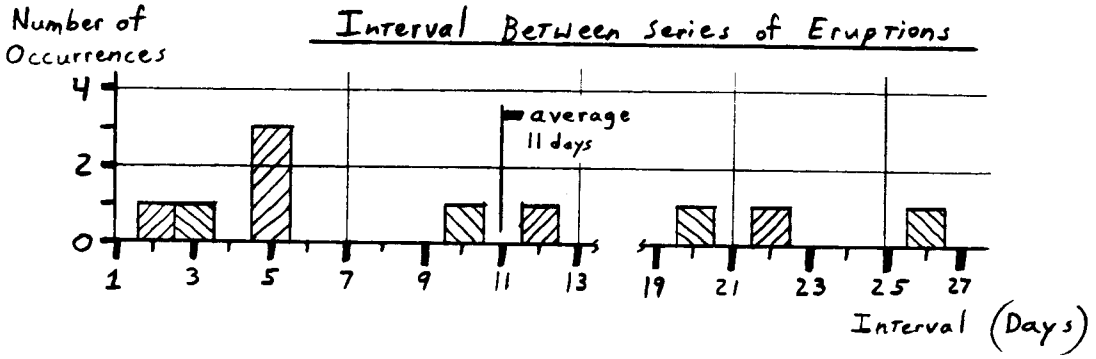
Eruption Interval Within Eruption Series



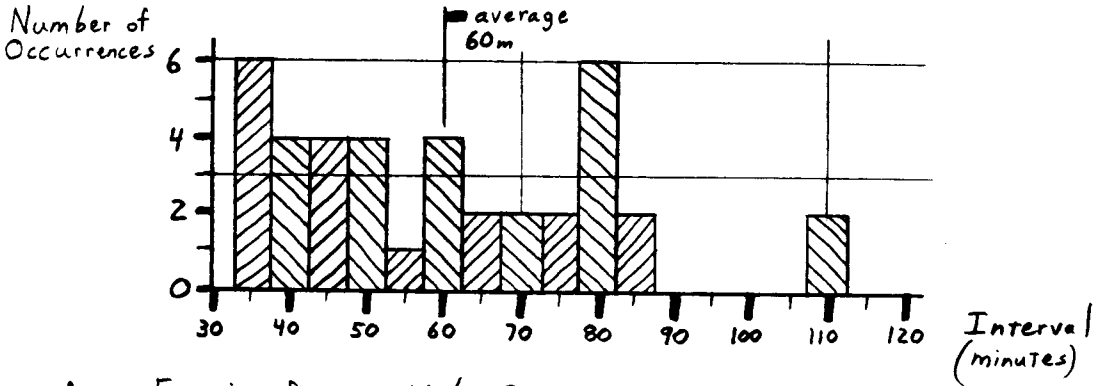
Eruption Duration Within Eruption Series



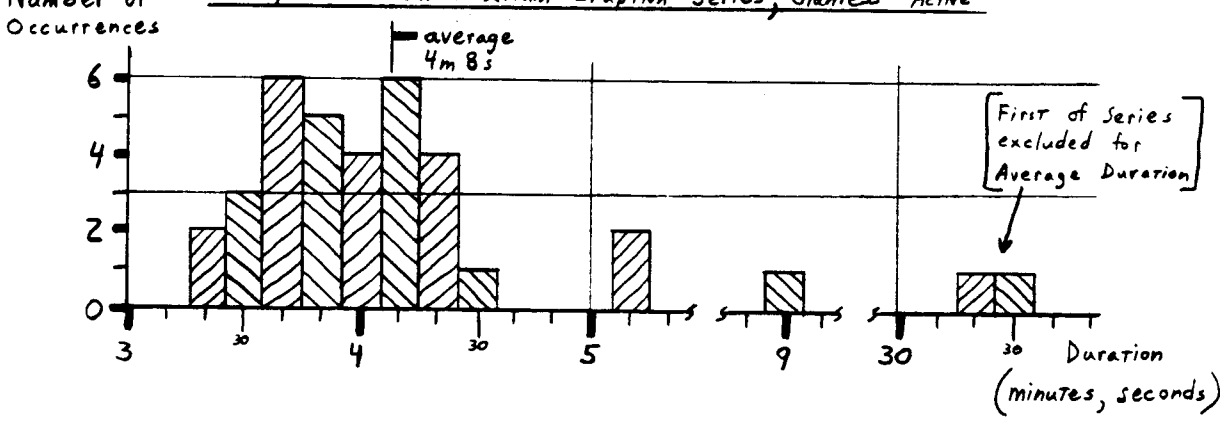
Interval Between Series of Eruptions

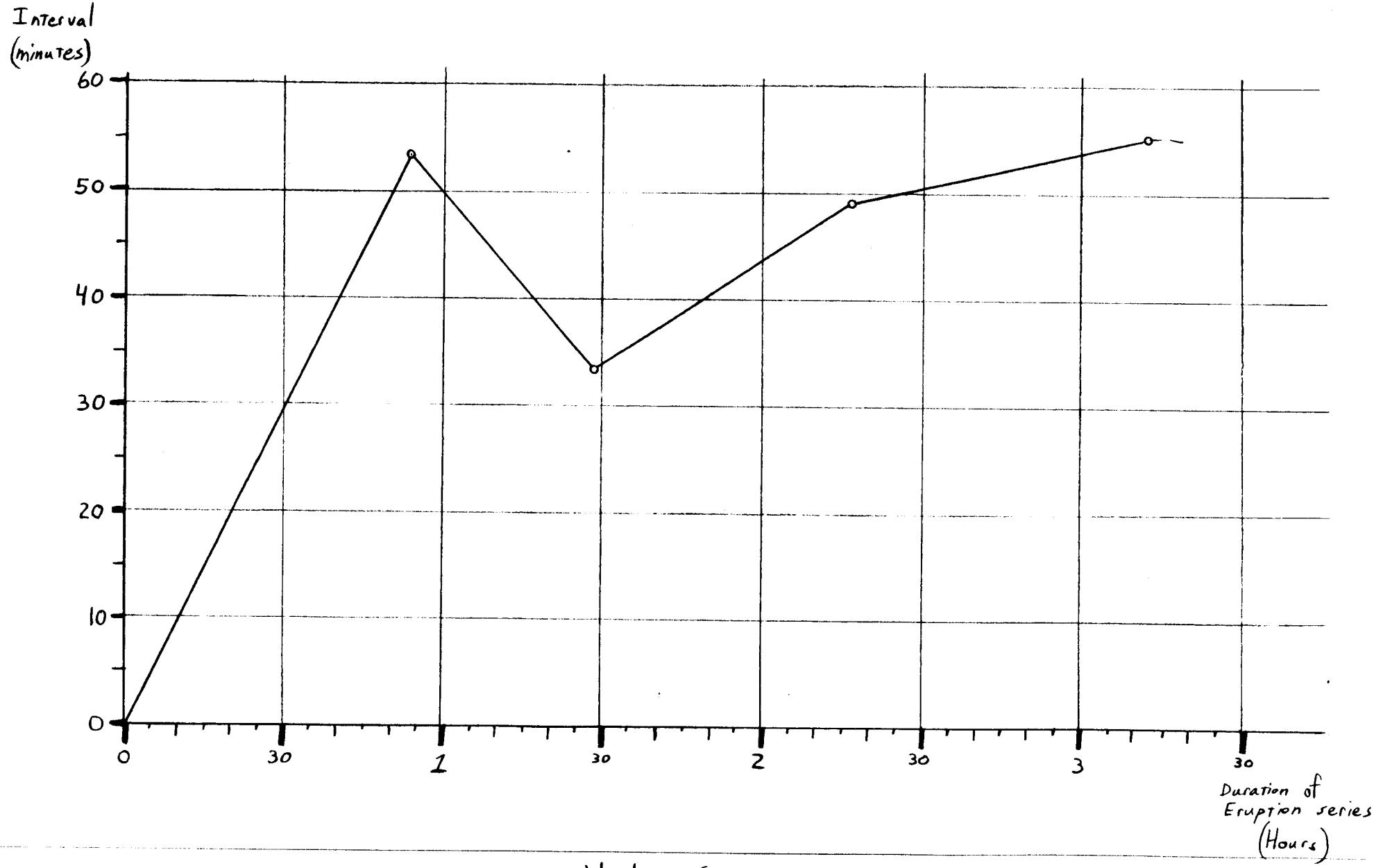


Eruption Interval Within Eruption Series, Giantess Active



Eruption Duration Within Eruption Series, Giantess Active





Vault Geyser

Eruption Series Start Up, June 13, 1988

NOW

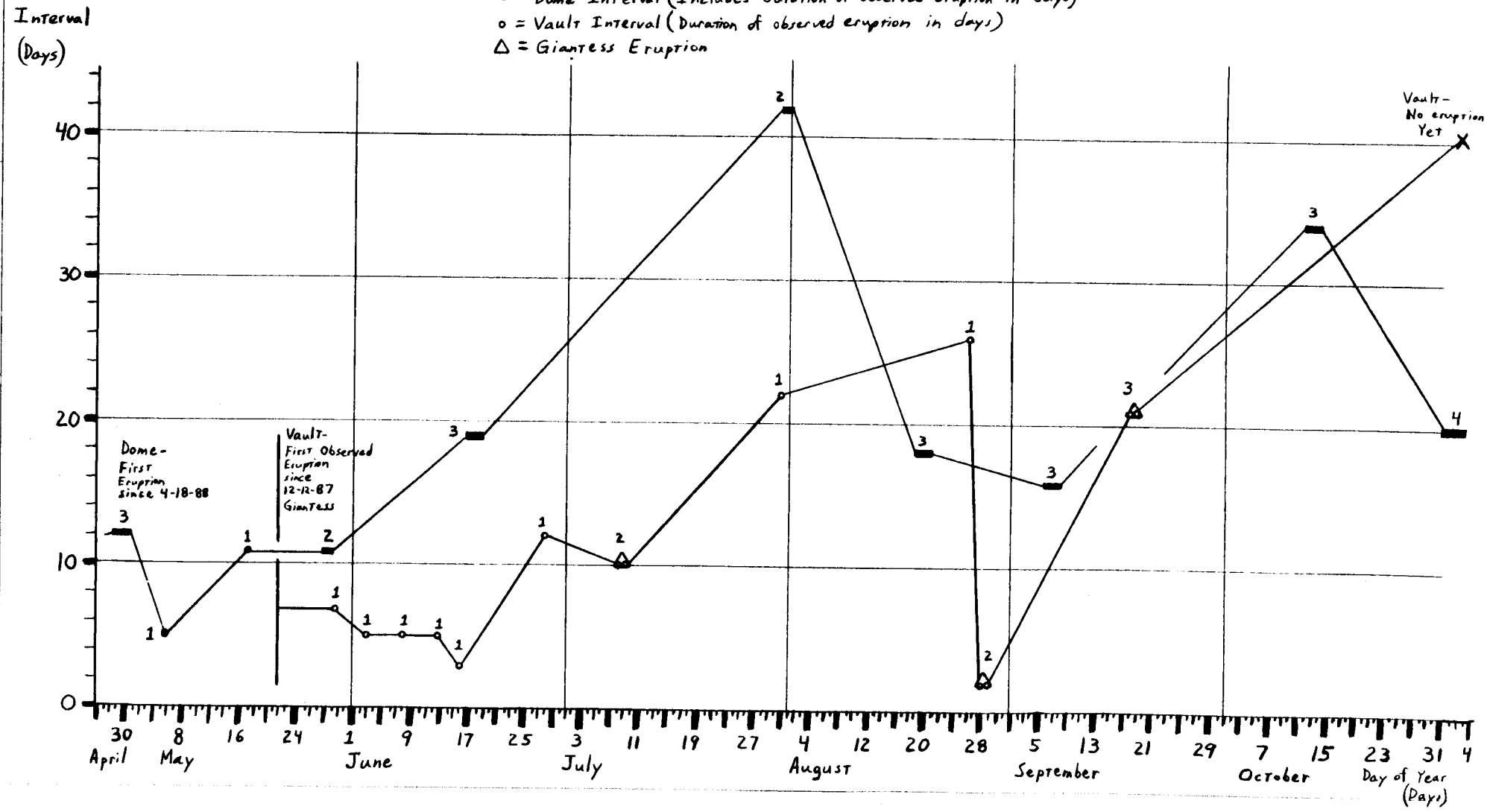
Vault + Dome Geysers

April 26 - November 4, 1988

● = Dome Interval (Includes duration of observed eruption in days)

o = Vault Interval (Duration of observed eruption in days)

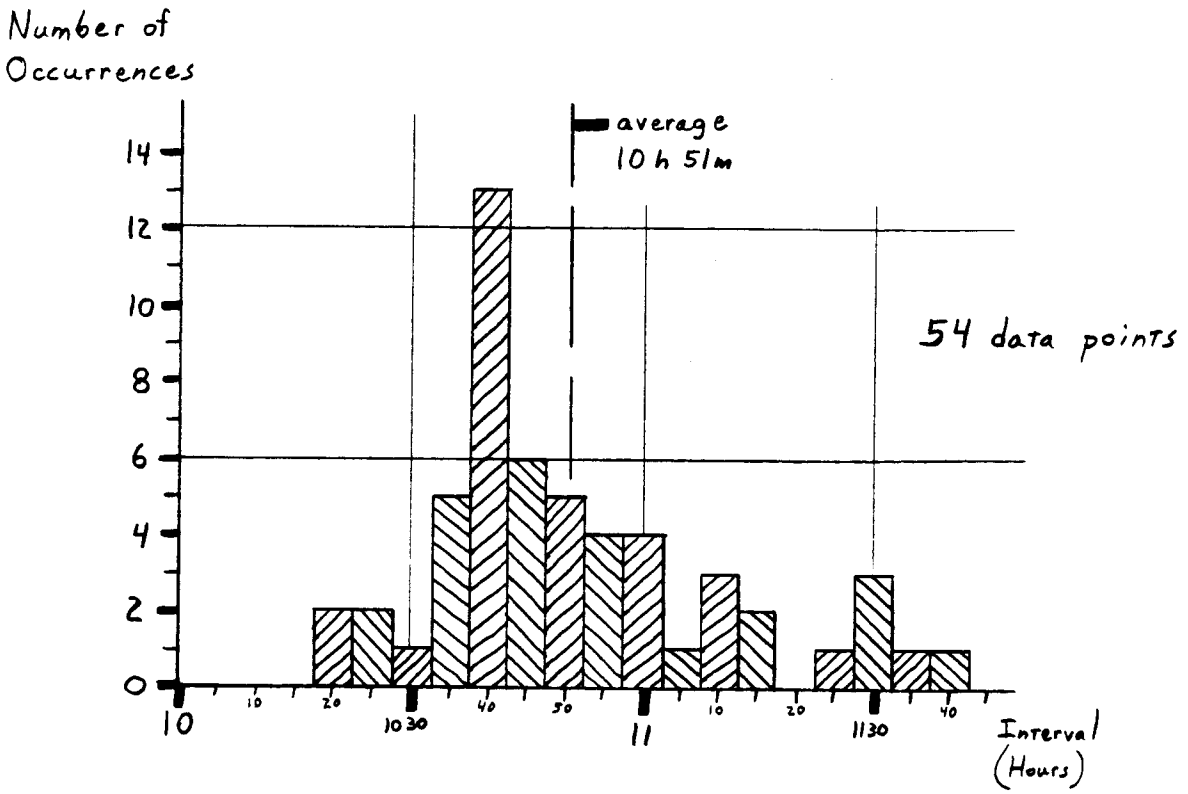
△ = Giantess Eruption



Castle Geyser

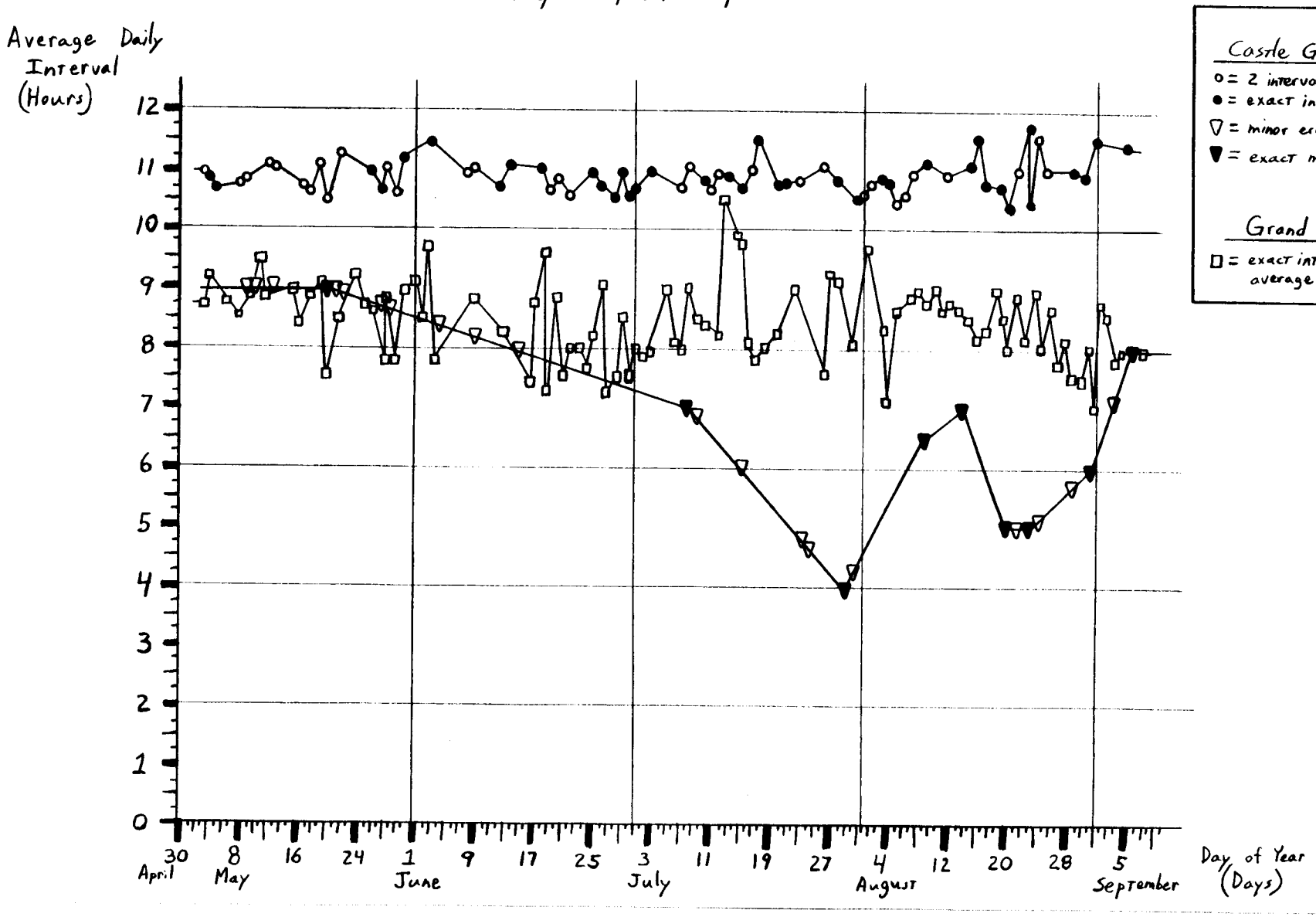
May 2 - October 6, 1988

Intervals Between Major Eruptions



Castle and Grand Geyser Eruption Intervals

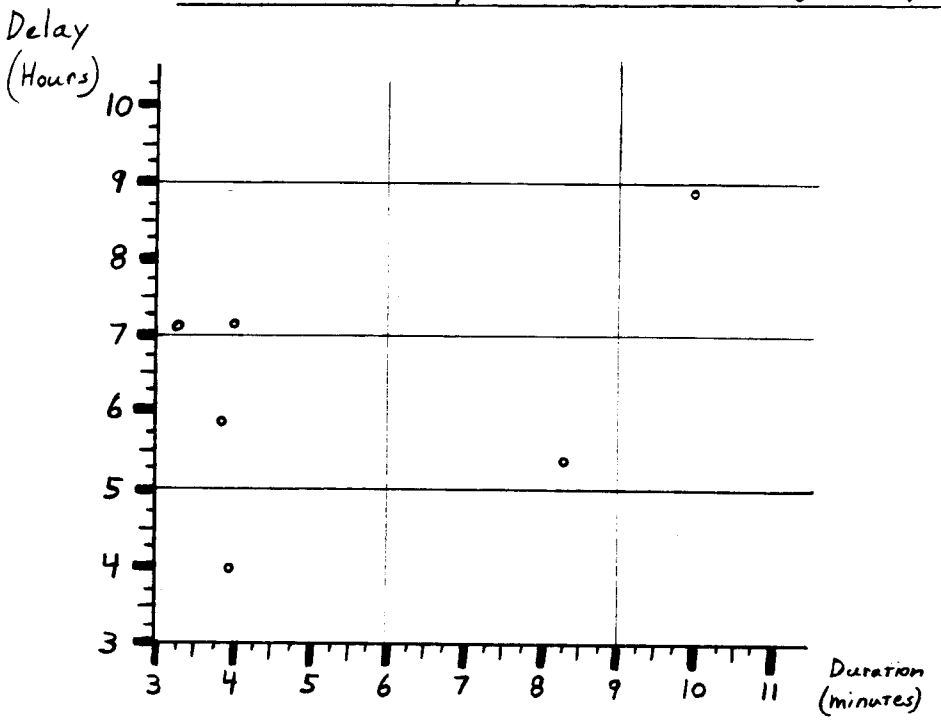
May 2 – September 6, 1988



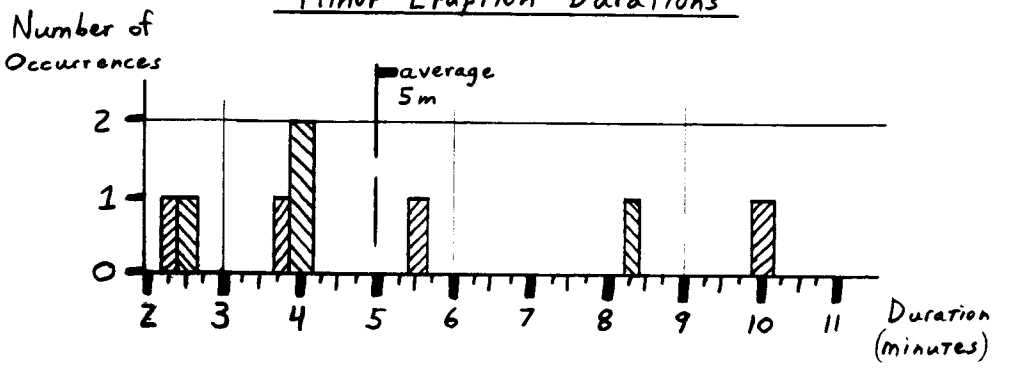
Castle Geyser

May 2 - September 6, 1988

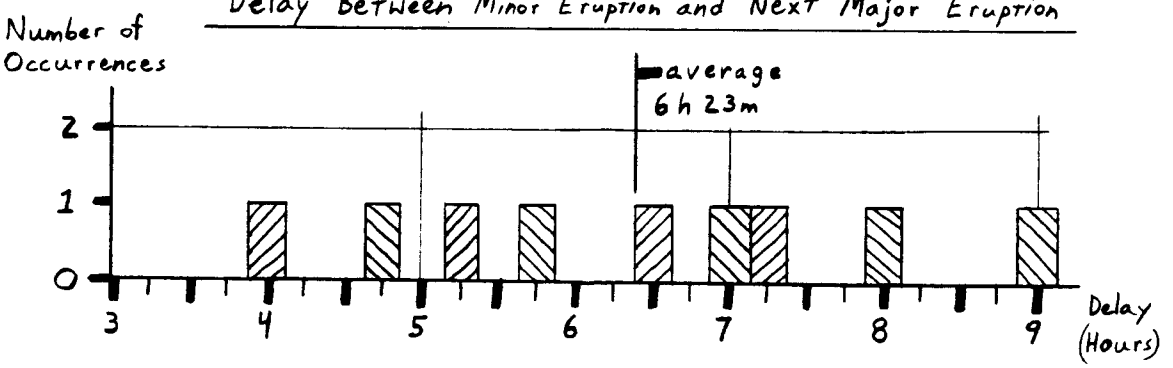
Minor Eruption Duration and Timespan (delay) Between Minor Eruption and the Next Major Eruption



Minor Eruption Durations



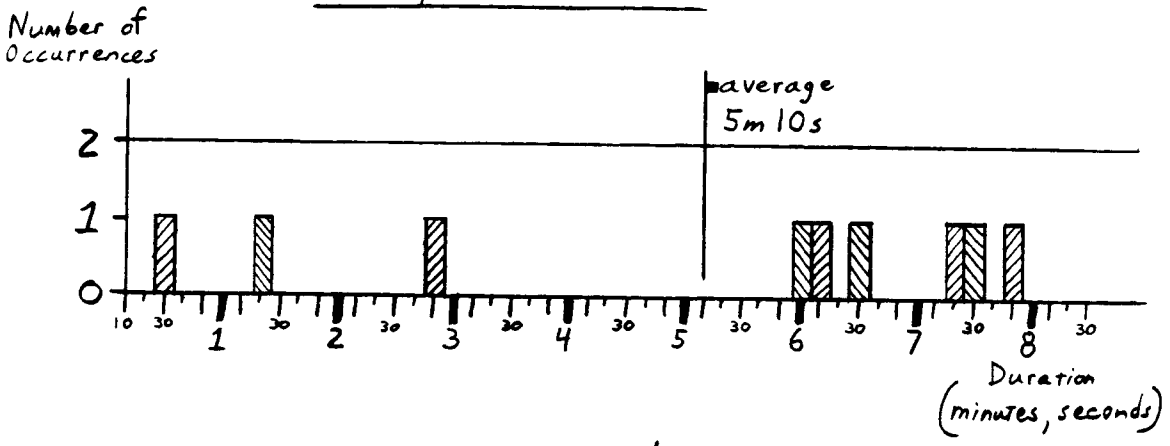
Delay Between Minor Eruption and Next Major Eruption



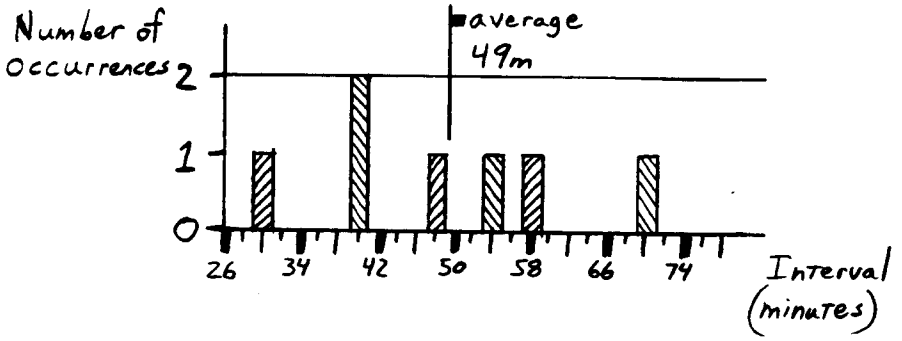
Bulger Geyser

May 1 - August 30, 1988

Eruption Duration



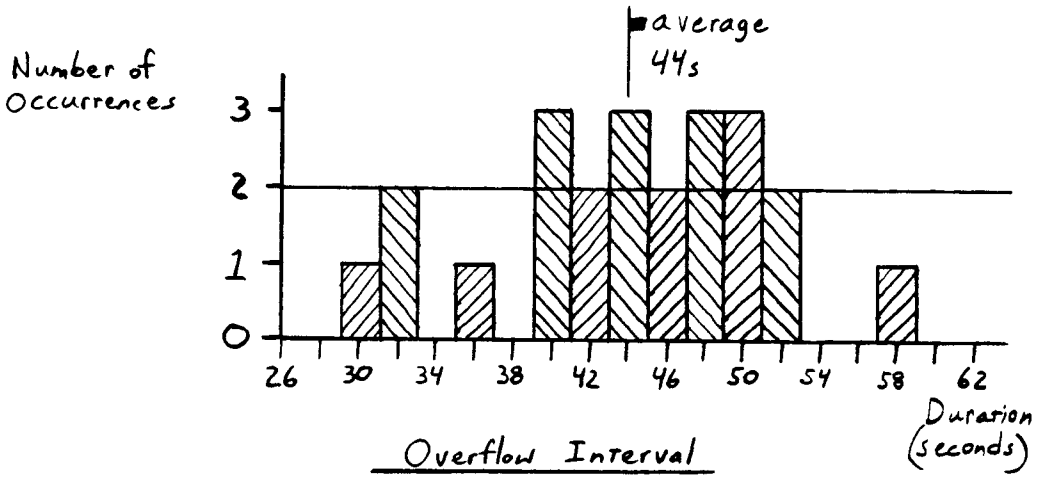
Eruption Interval



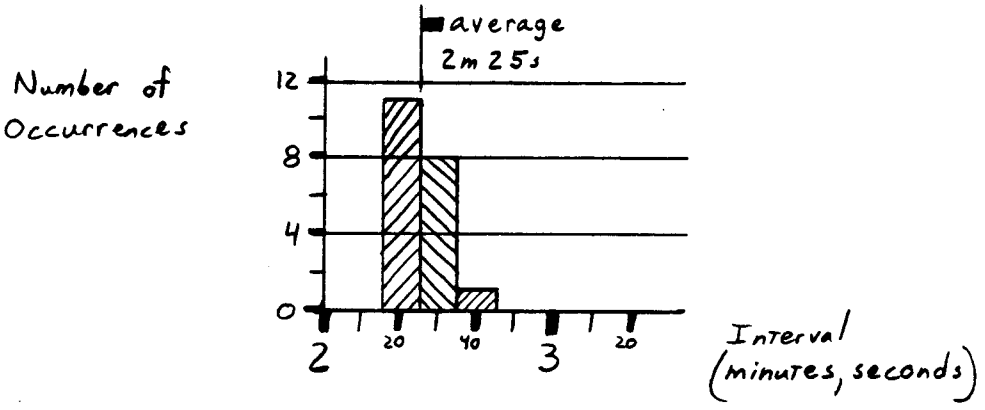
Crystal Spring

May 1 - August 30, 1988

Overflow Duration



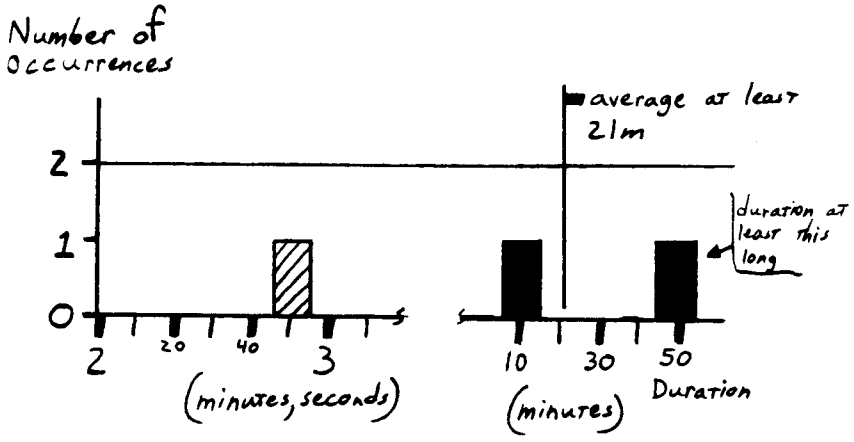
Overflow Interval



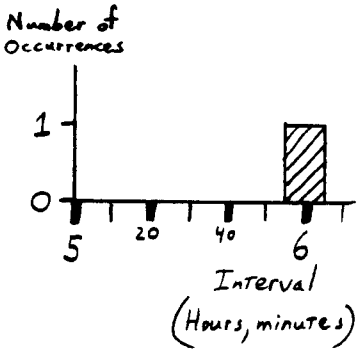
Tardy Geyser

May 1 - August 30, 1988

Eruption Duration



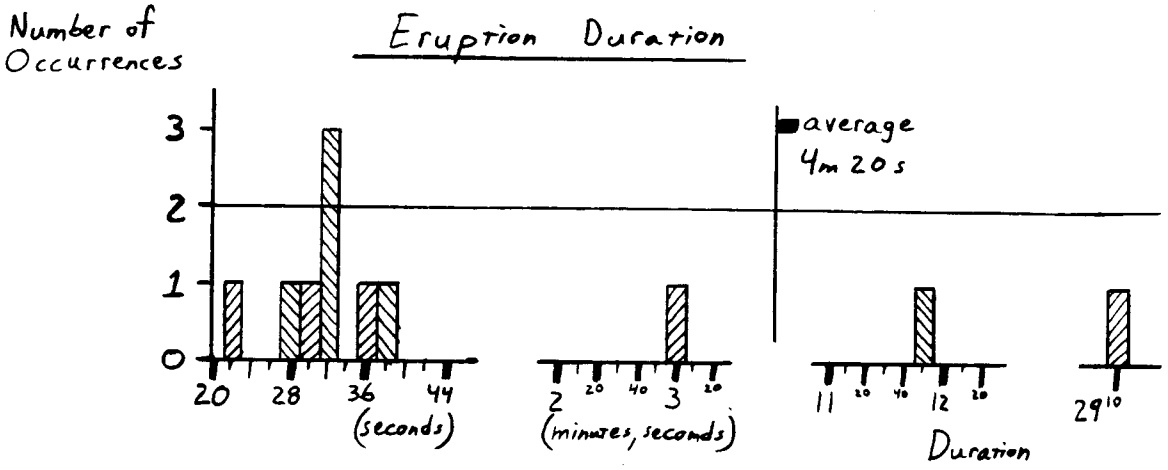
Eruption Interval



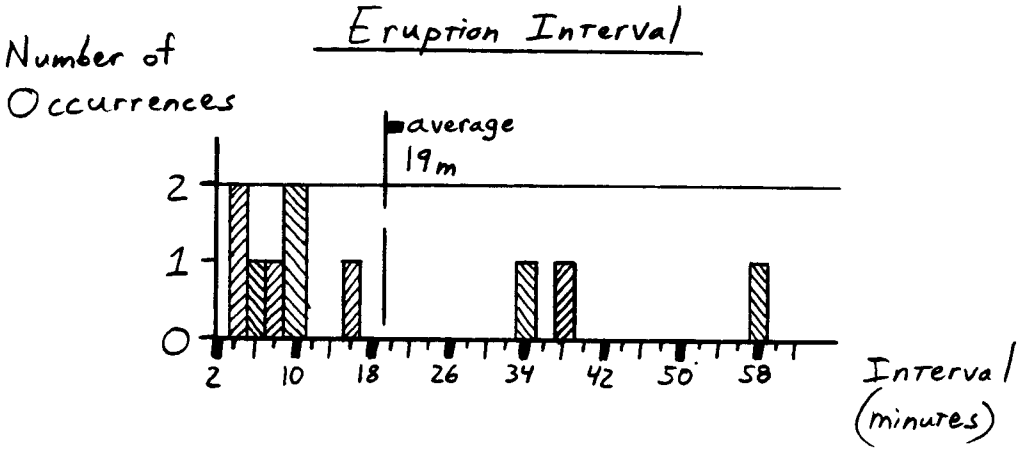
Old Tardy Geyser

May 1 - August 30, 1988

Eruption Duration



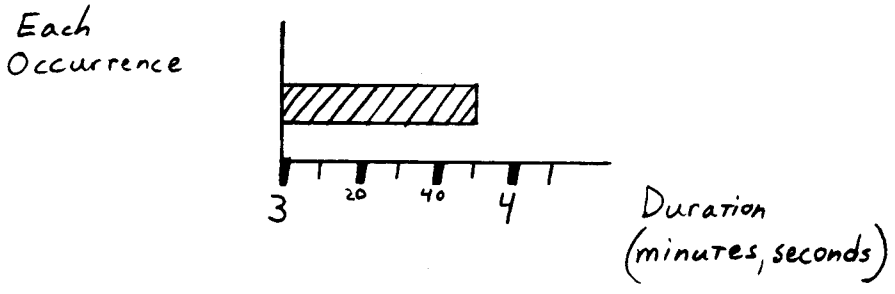
Eruption Interval



Uncertain Geyser

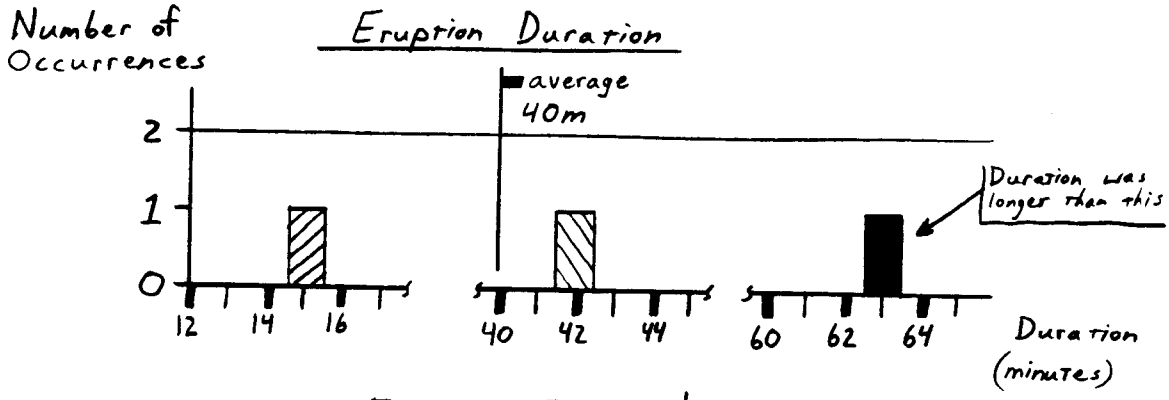
May 1988

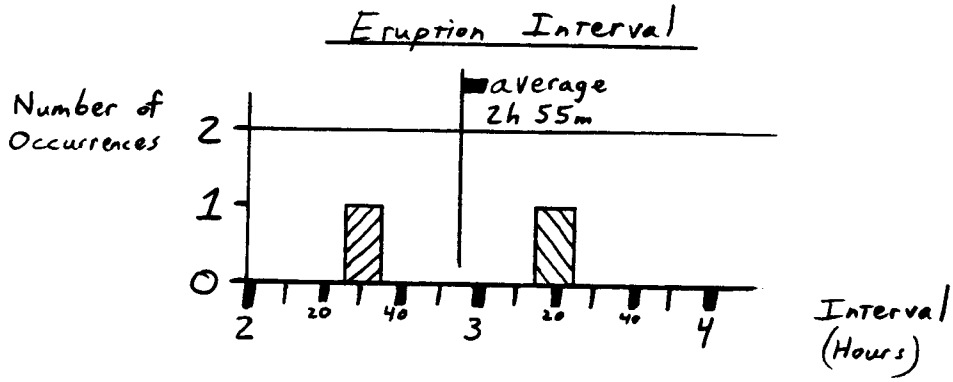
Eruption Duration



Sawmill Geyser

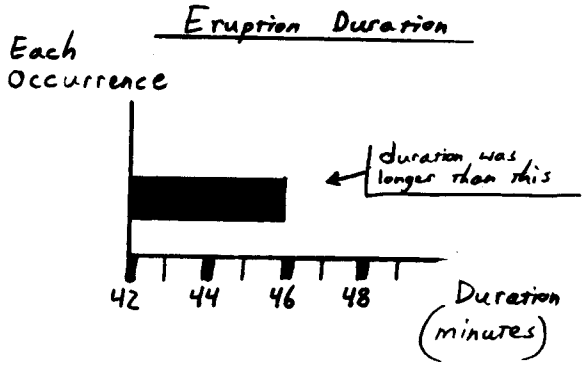
May 1 – August 30, 1988

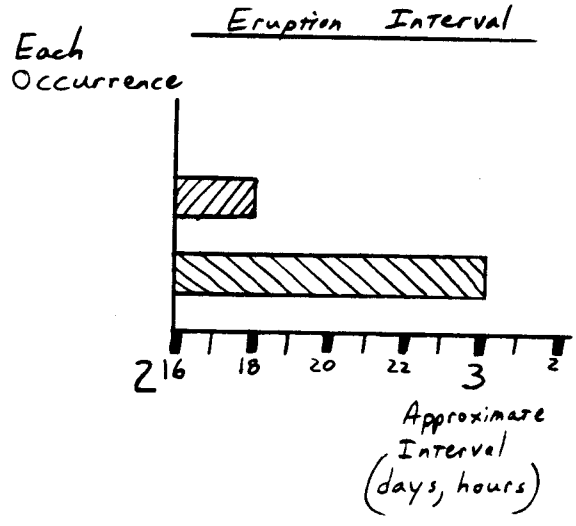




Penta Geyser

May 1 – August 30, 1988

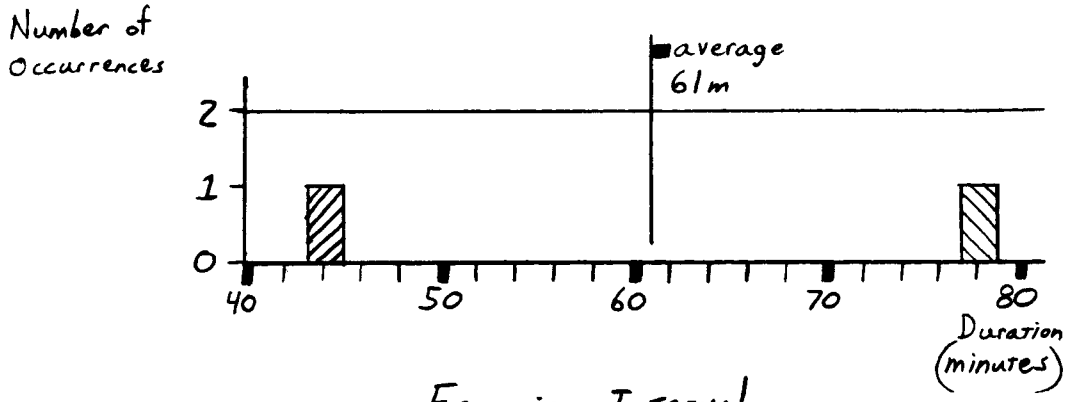




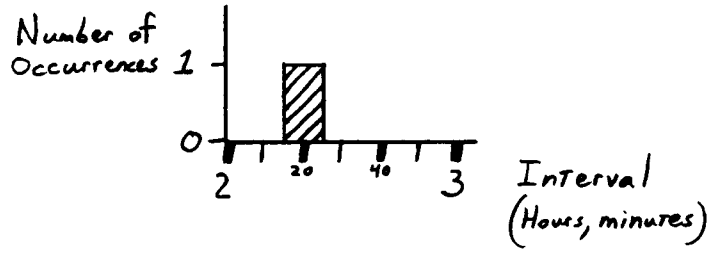
Spasmodic Geyser

May 1 - August 30, 1988

Eruption Duration



Eruption Interval



Grand Geyser

May 2 - September 6, 1988

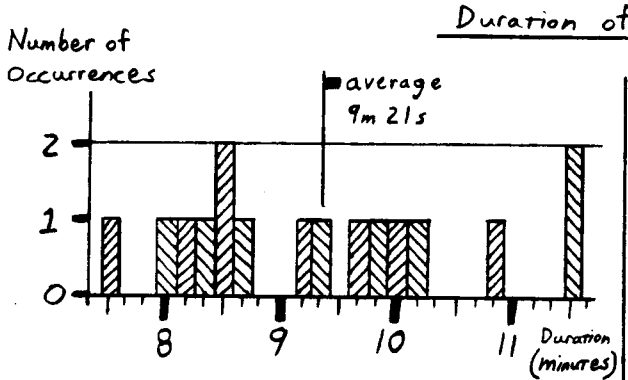
Grand Erupts Before Turban

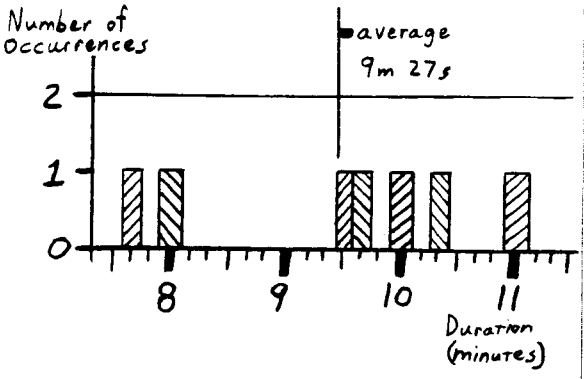
(One 4TH Burst Duration of 30 seconds)

Turban Erupts Before Grand

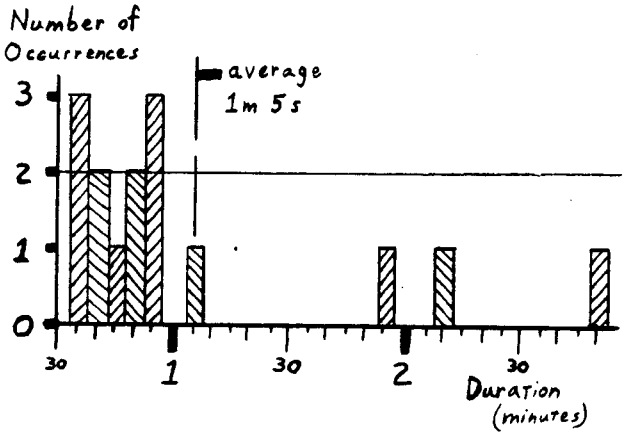
(No 4TH Burst Durations Recorded)

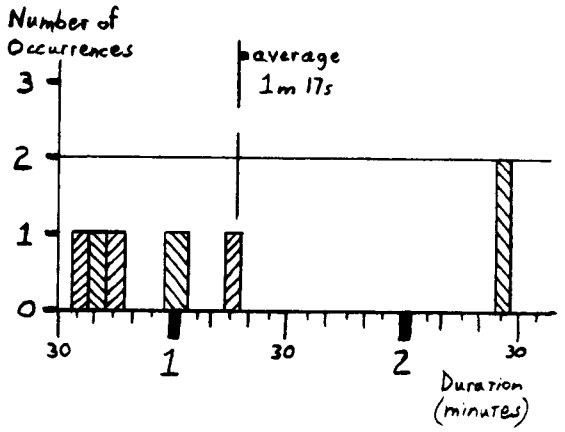
Duration of First Burst



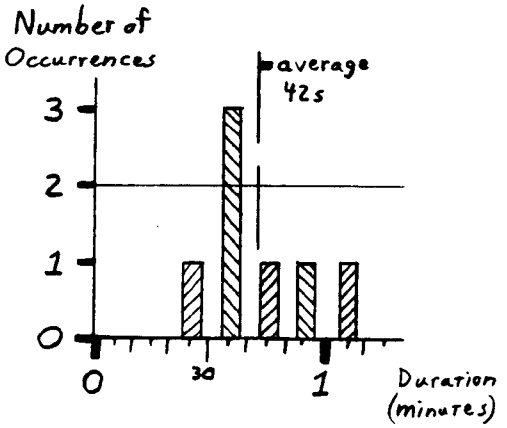


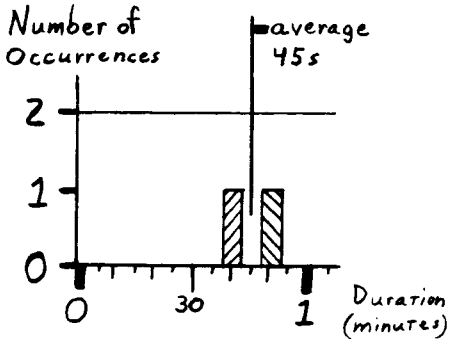
Duration of Second Burst





Duration of Third Burst





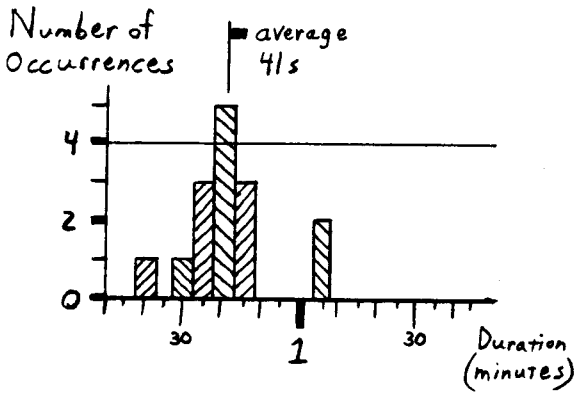
Grand Geyser

May 2 - September 6, 1988

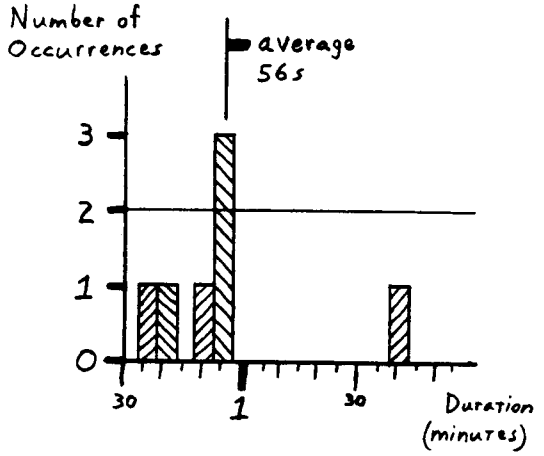
Grand Erupts Before Turban

(One pause between 3rd & 4th burst of 50 seconds)

Duration of Pause Between First and Second Bursts

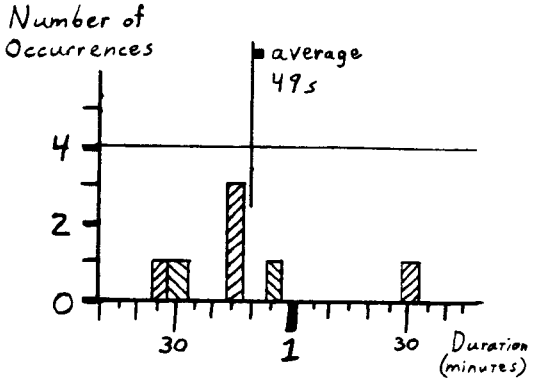


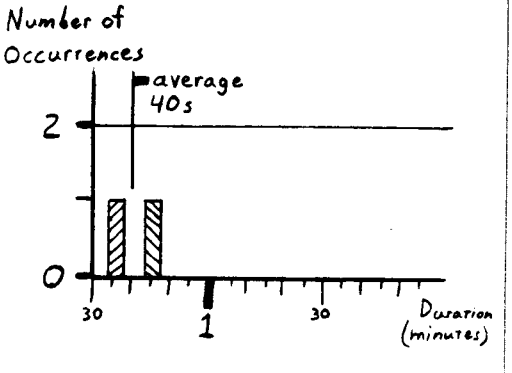
Duration of Pause Between Second and Third Bursts



Turban Erupts Before Grand

(No pause between 3rd & 4th burst observed)





Grand Geyser

Record Burst (for me) that I observed

Date: May 21, 1988

Time: 2000.05 (eruption begins)

Bursts: 3

Duration: 12 min. 8 sec.

Observations: The eruption's second burst did NOT fit into a photo using a 35mm camera with a 28mm lense.

Calculations

28mm lense has an angle of view of 64°
Base like was 116 feet
all dimensions in feet

Fig. 1

$\tan\theta = \frac{6}{116}$, $\theta = 3°$

$\phi = 90 - (58+3)$, $\phi = 29°$

$N = \sqrt{6^2 + 116^2}$, $N = 116.2'$

$\sin 32° = \frac{P/2}{N}$, $P = 123.1'$

Fig. 1

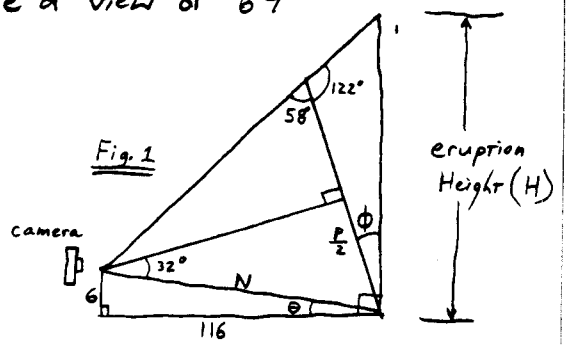


Fig. 2+3

$\sin 29° = \frac{R}{123.1}$, $R = 59.7'$

$\cos 29° = \frac{V}{123.1}$, $V = 107.7'$

Fig. 2

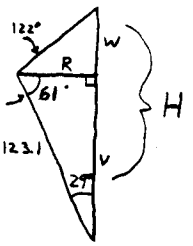


Fig. 4

$\tan 61° = \frac{W}{R}$, $W = 107.7'$

Fig. 1+2

$H = W + V$, $H = 215'$

$H = 215$ feet

Fig. 3

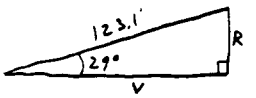
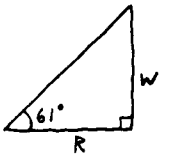
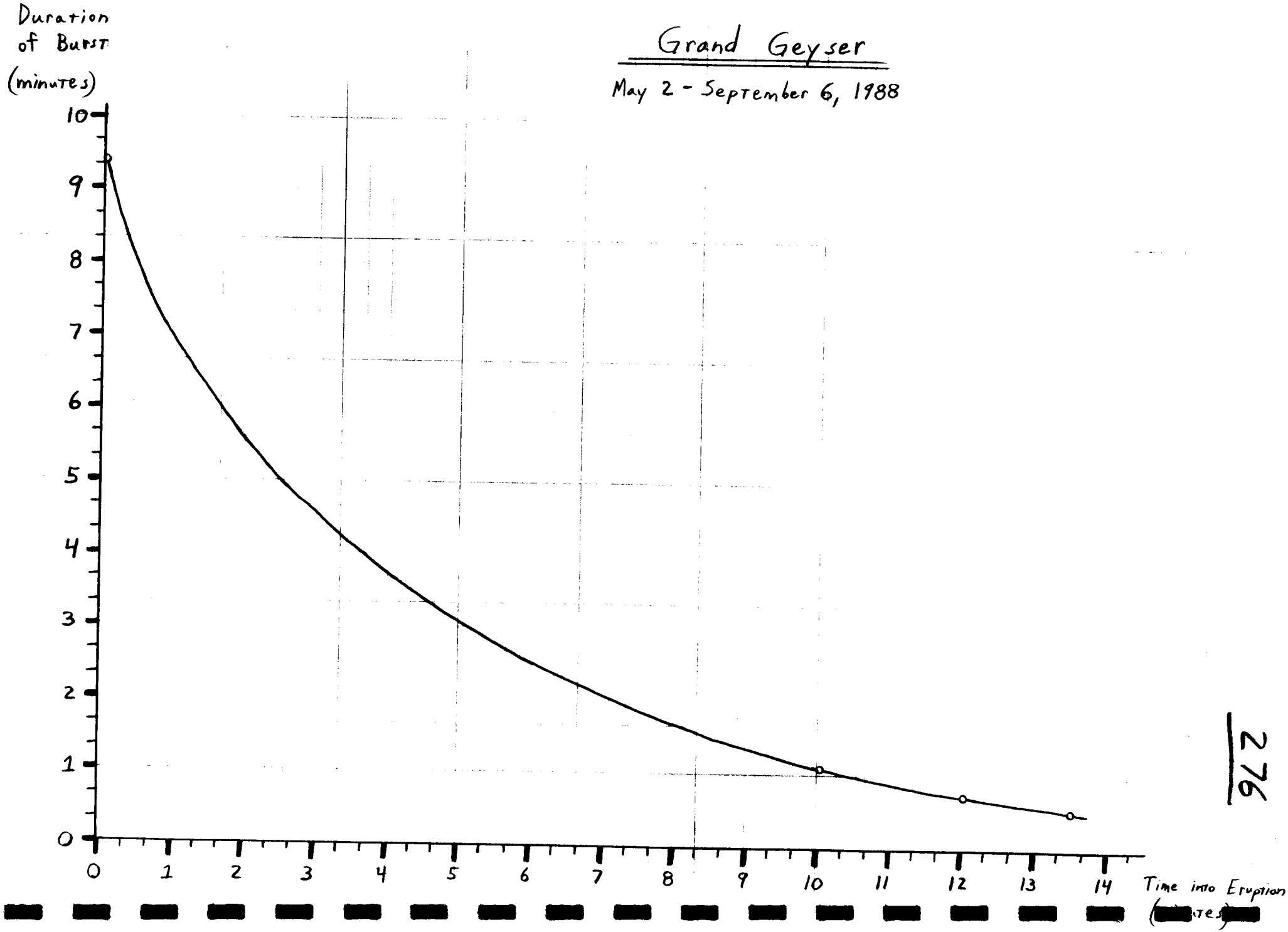


Fig. 4



Grand Geyser

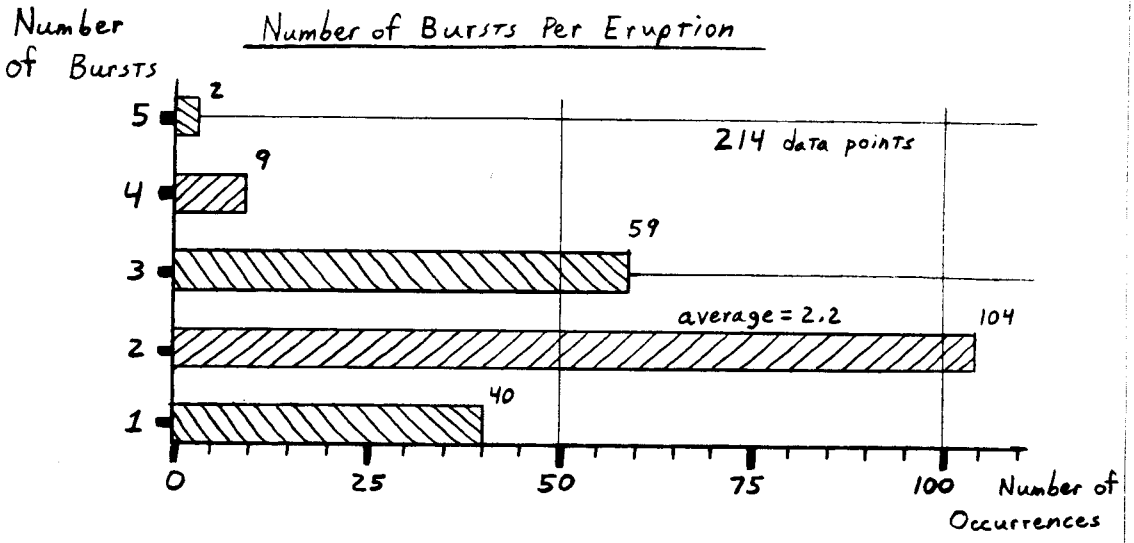
May 2 - September 6, 1988

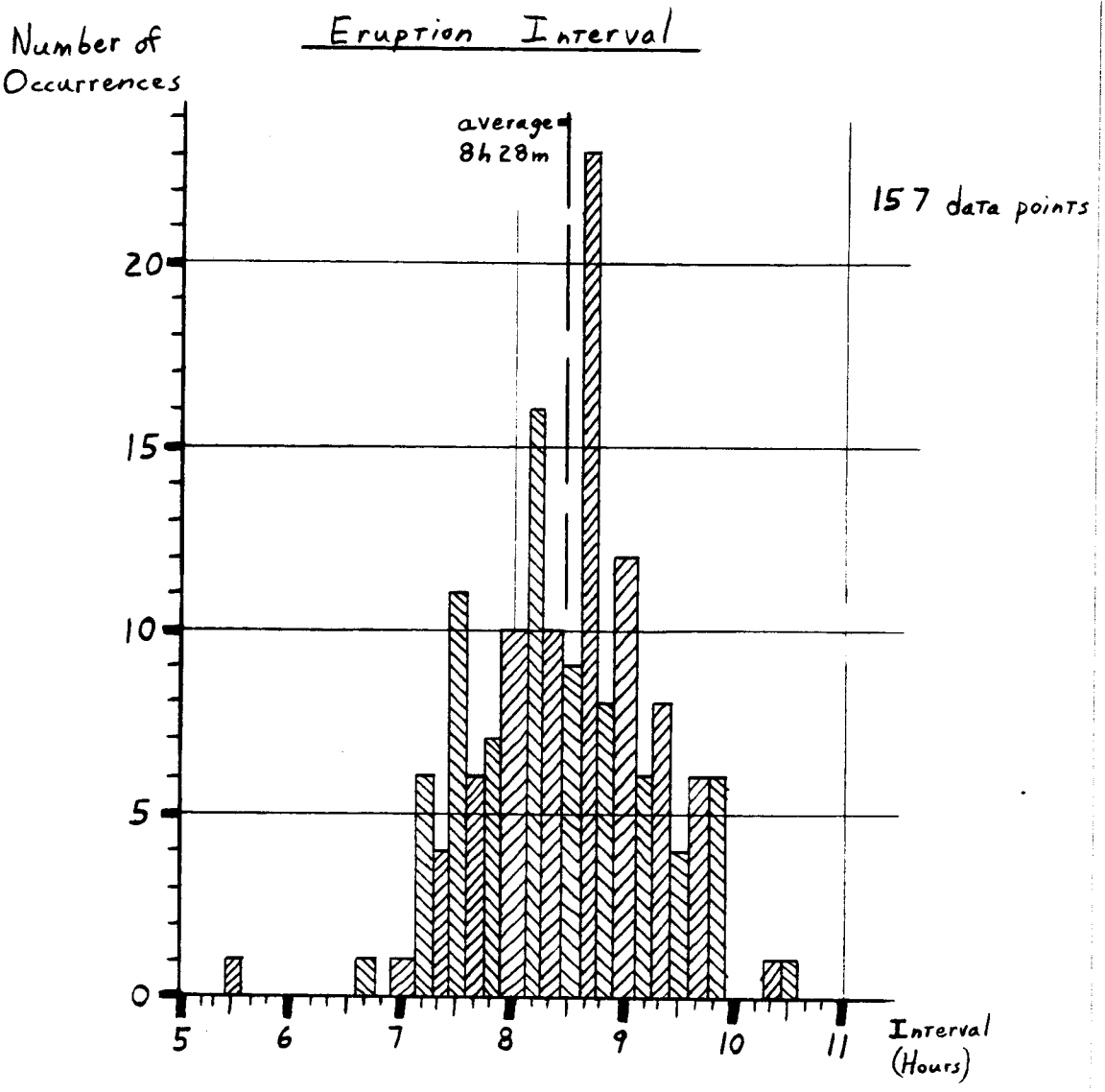


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Grand Geyser

May 2 - September 6, 1988





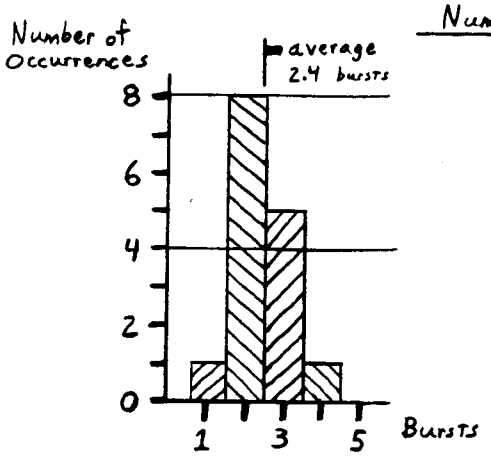
Grand Geyser

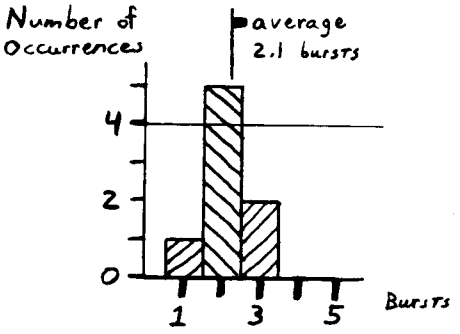
May 2 - September 6, 1988

Grand Erupts Before Turban

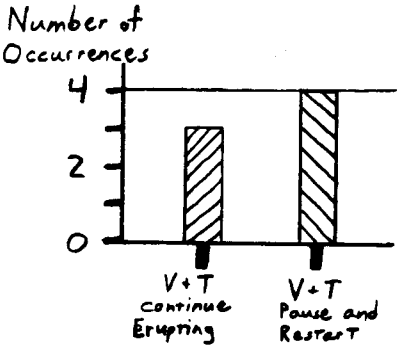
Turban Erupts Before Grand

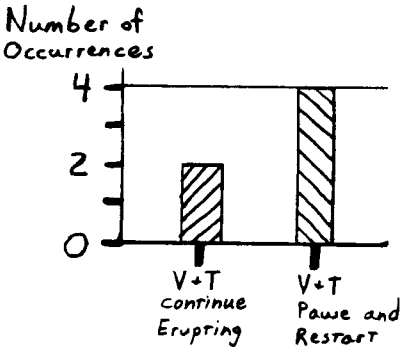
Number of Bursts Per Eruption



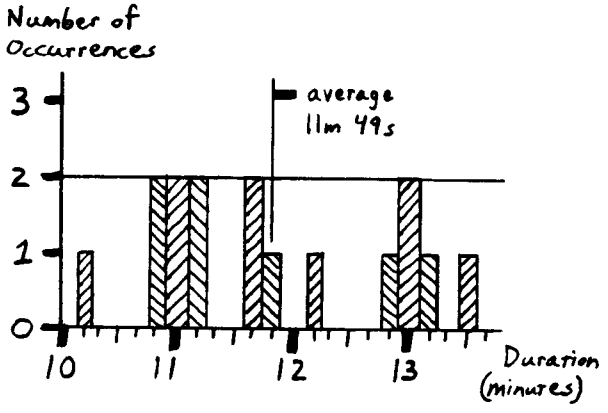


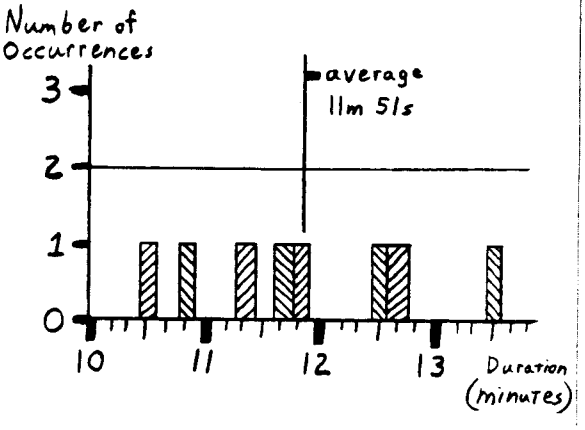
Vent and Turban Activity after Grand's Eruption Ends





Total Eruption Duration

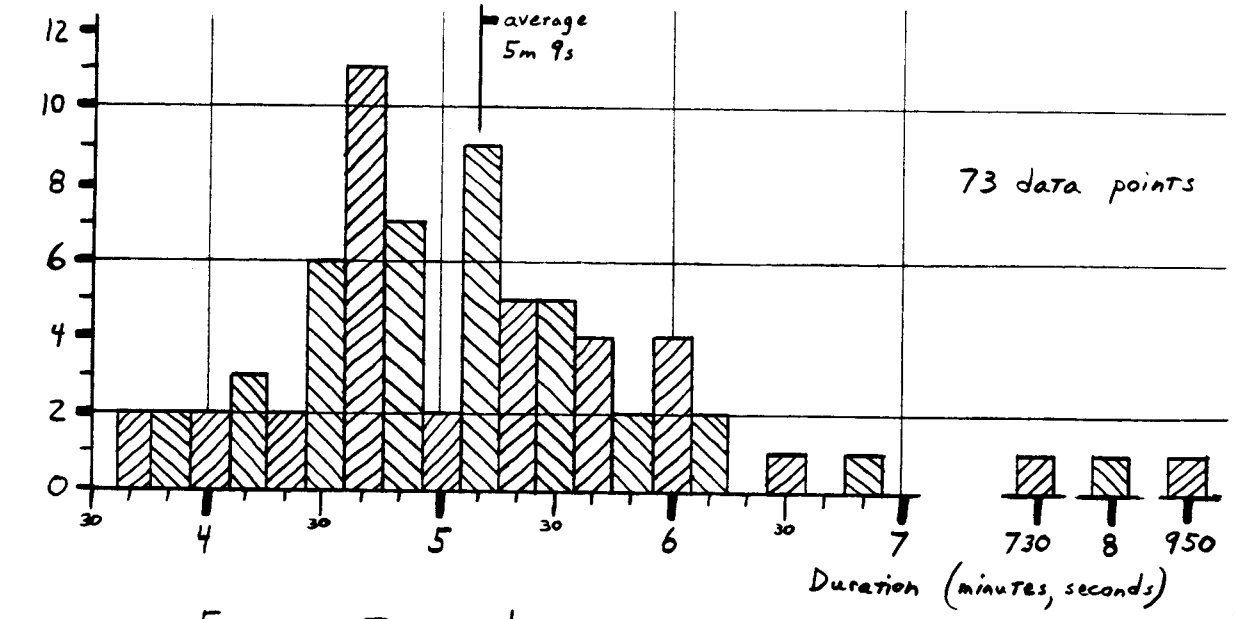




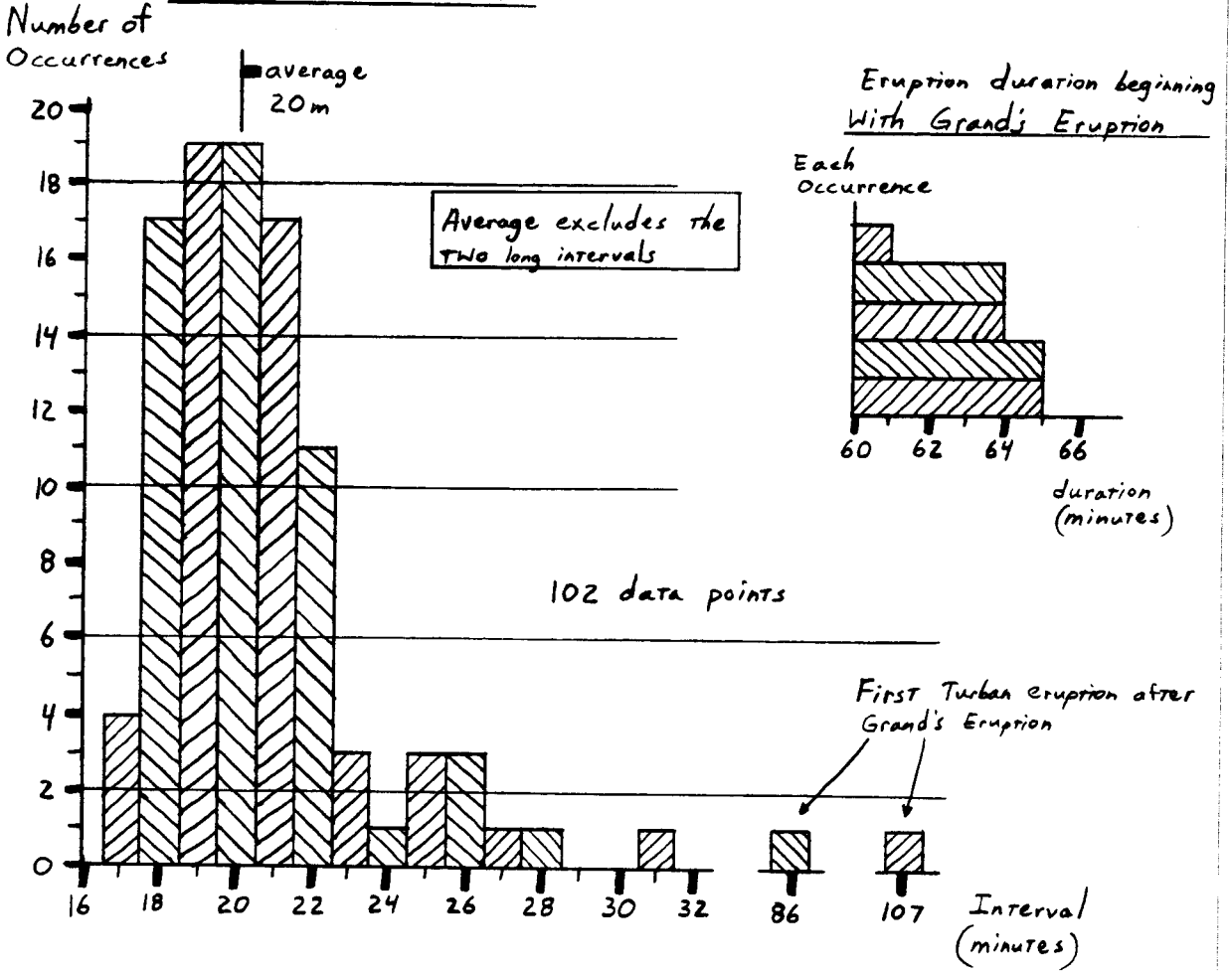
Turban Geyser

April 26 - October 31, 1988

Eruption Duration

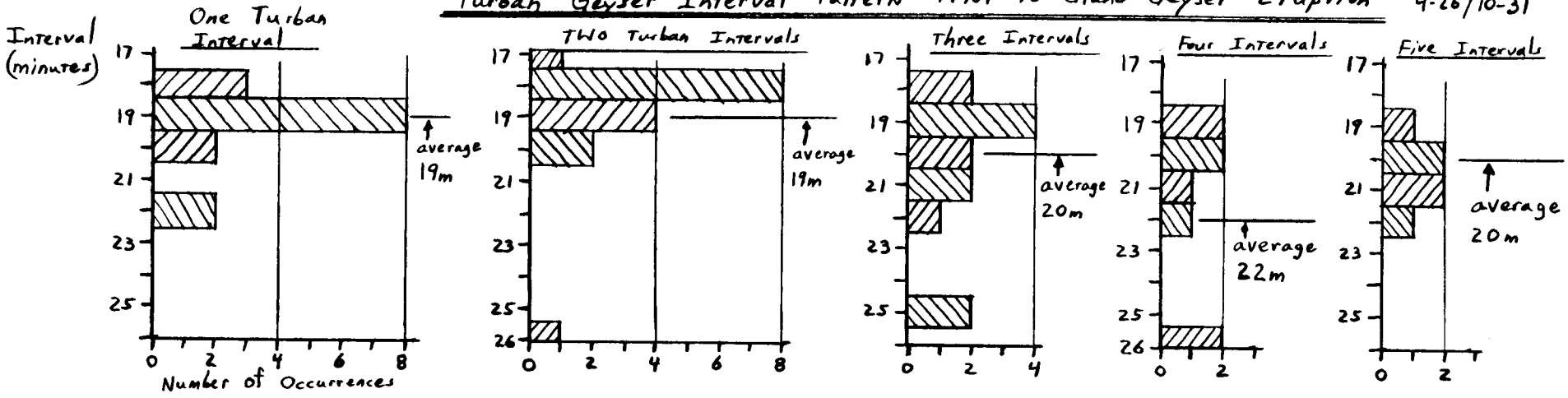


Eruption Interval

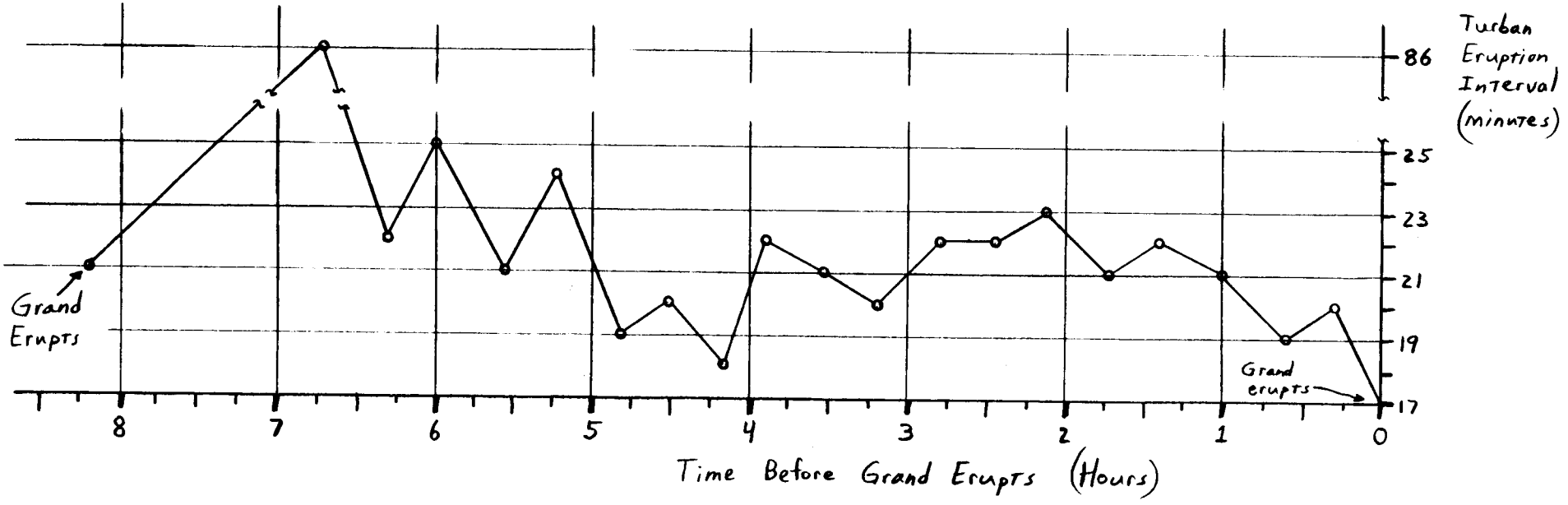


Eruption duration beginning with Grand's Eruption

Turban Geyser Interval Pattern Prior to Grand Geyser Eruption 4-26/10-31



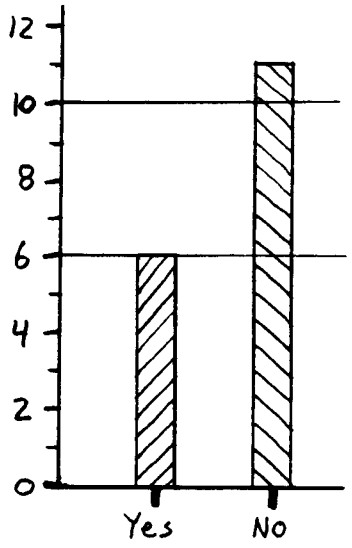
Turban Geyser Eruption Intervals 7-16-88



Turban Geyser

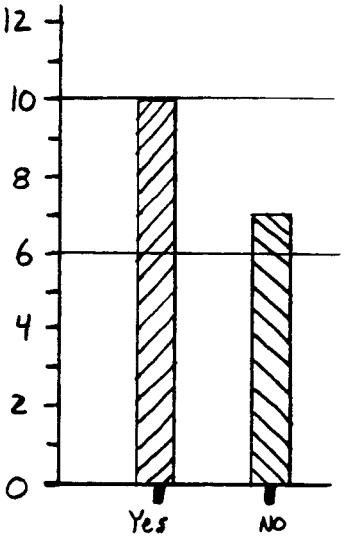
May 1 - September 30, 1988

Turban Erupts Before Grand Erupts

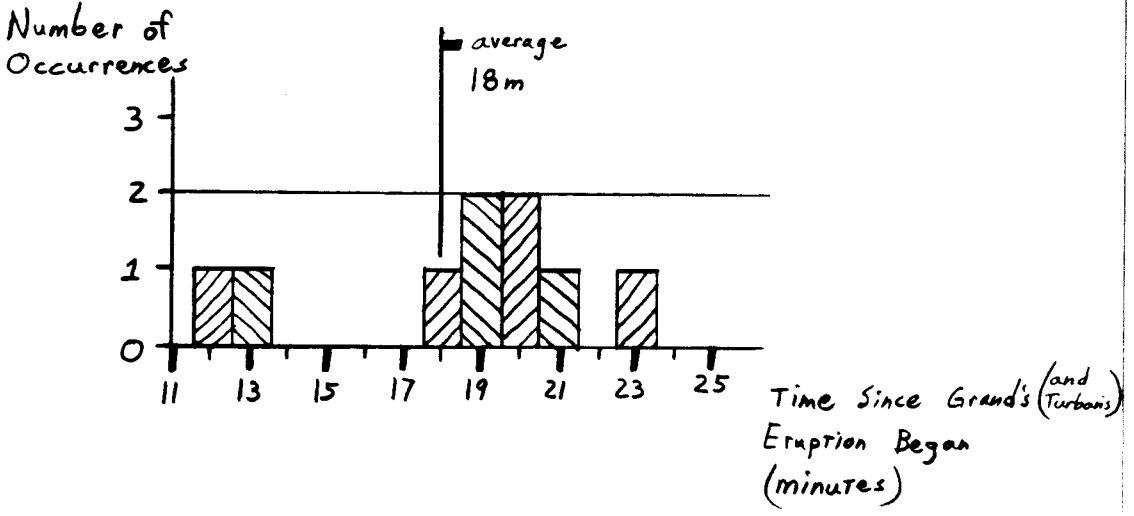


-AND-

Turban Stops After Grand's Eruption Ends



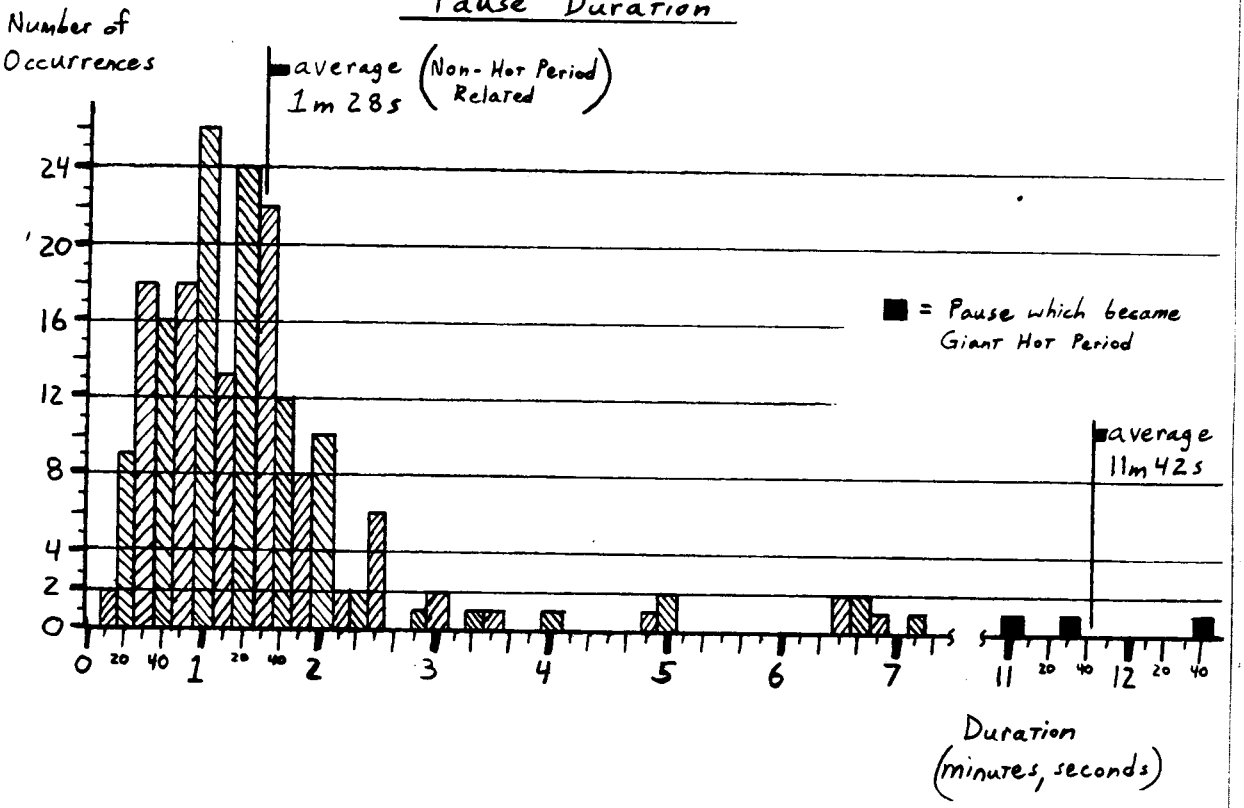
Turban Interval when Turban stops after Grand's Eruption ends, and then restarts to continue erupting for about another 40 minutes.



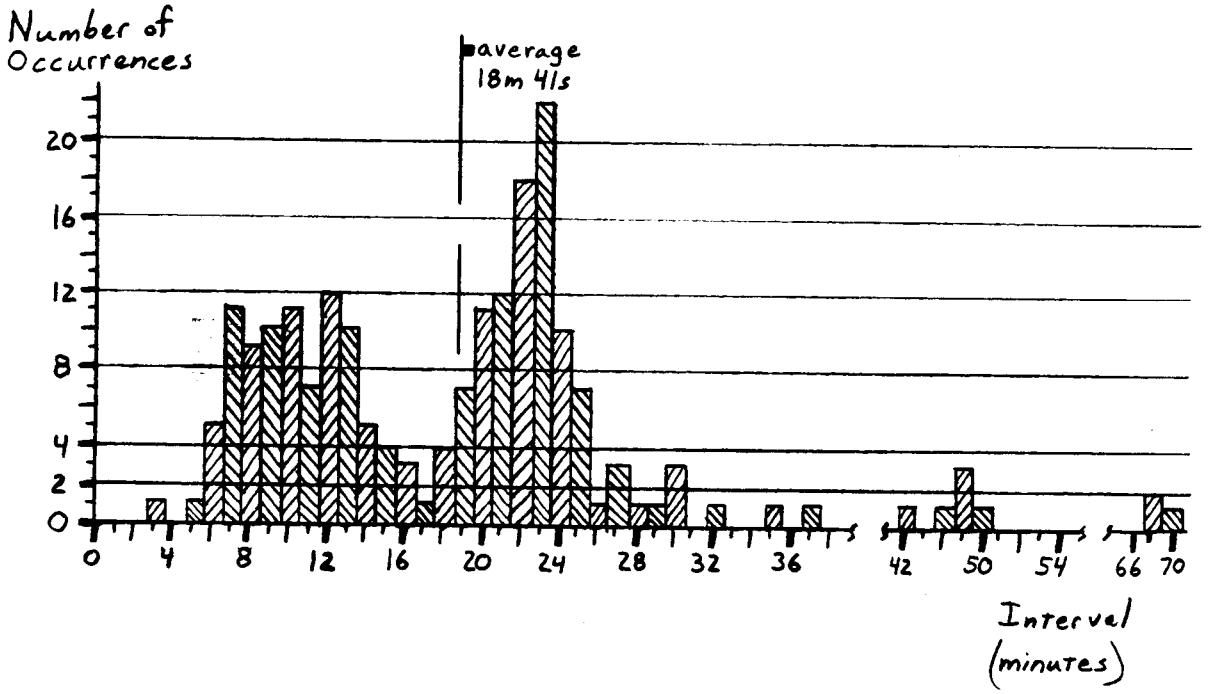
Bijou Geyser

August 1 - October 10, 1988

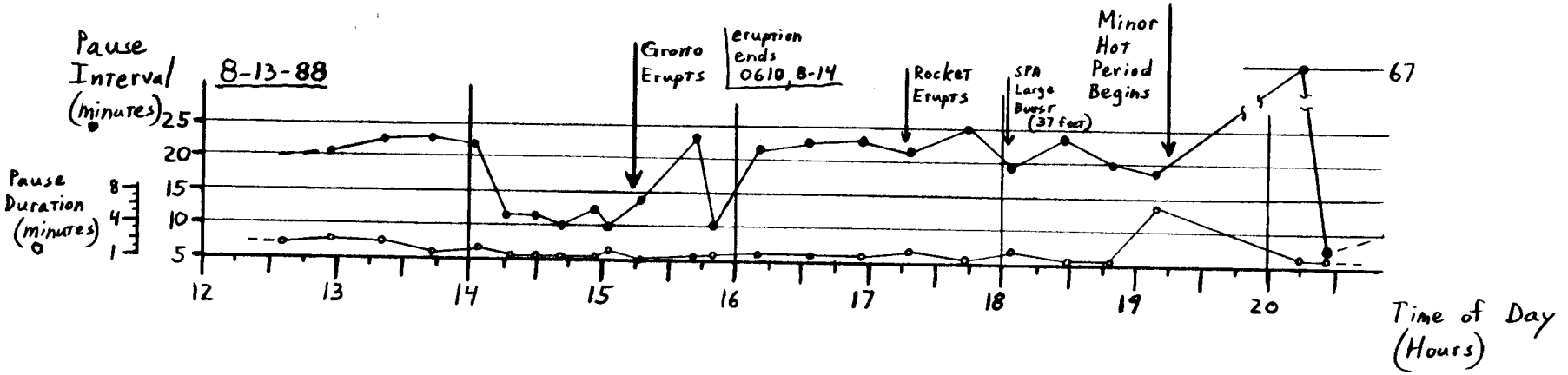
Pause Duration

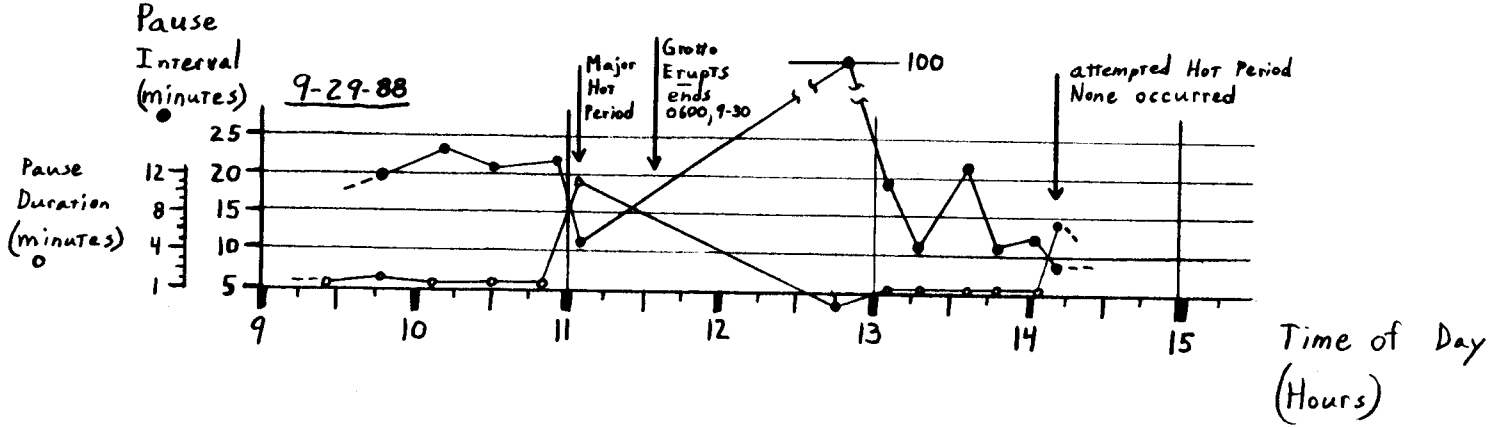


Pause Interval



Bijou, Grotto Activity Examples





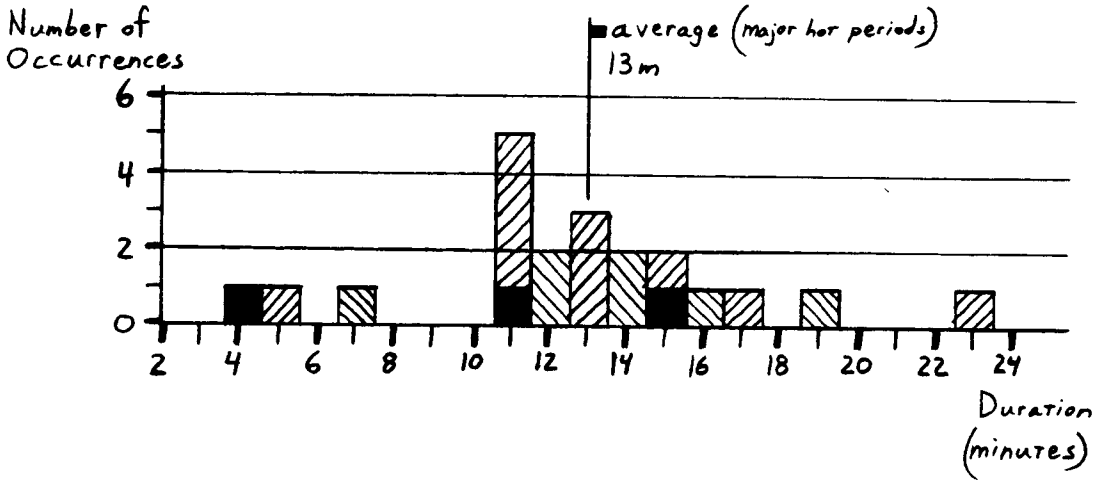
Giant Geyser

August - November, 1988

Hot Period Duration

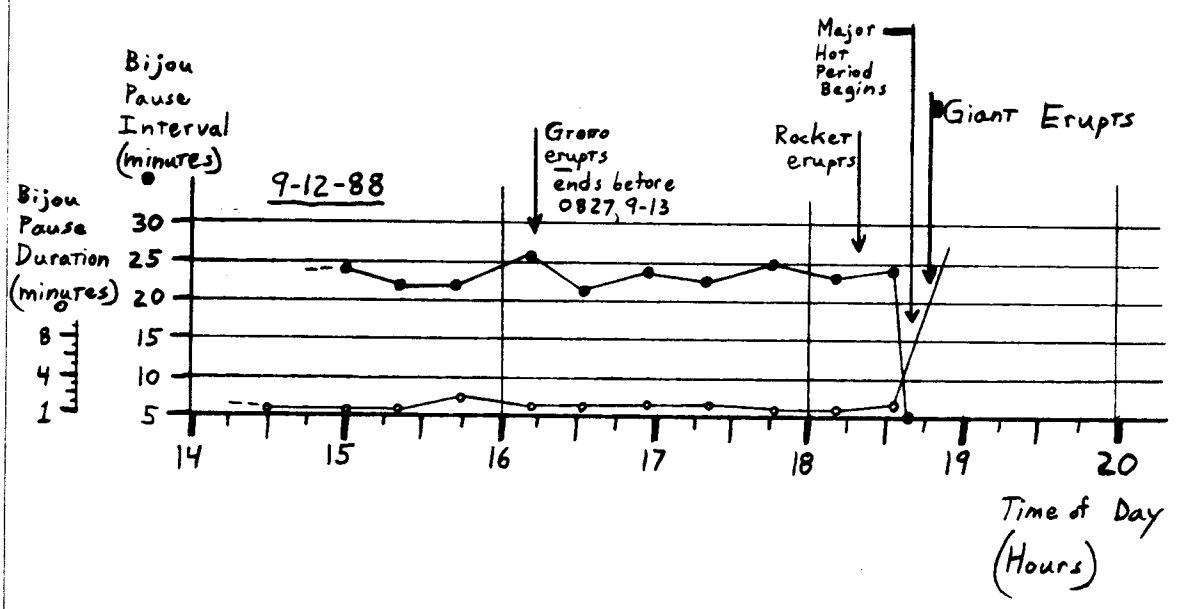
■ = minor hot period

▨, ▧ = major hot period



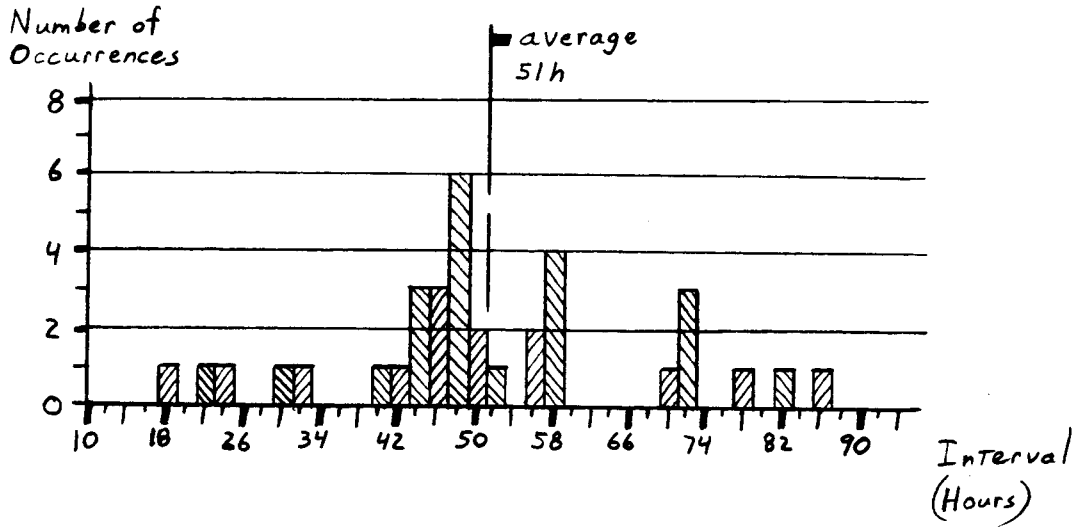
Activity on September 12, 1988

All data collected by Lynn Stephens + Mary Ann Moss



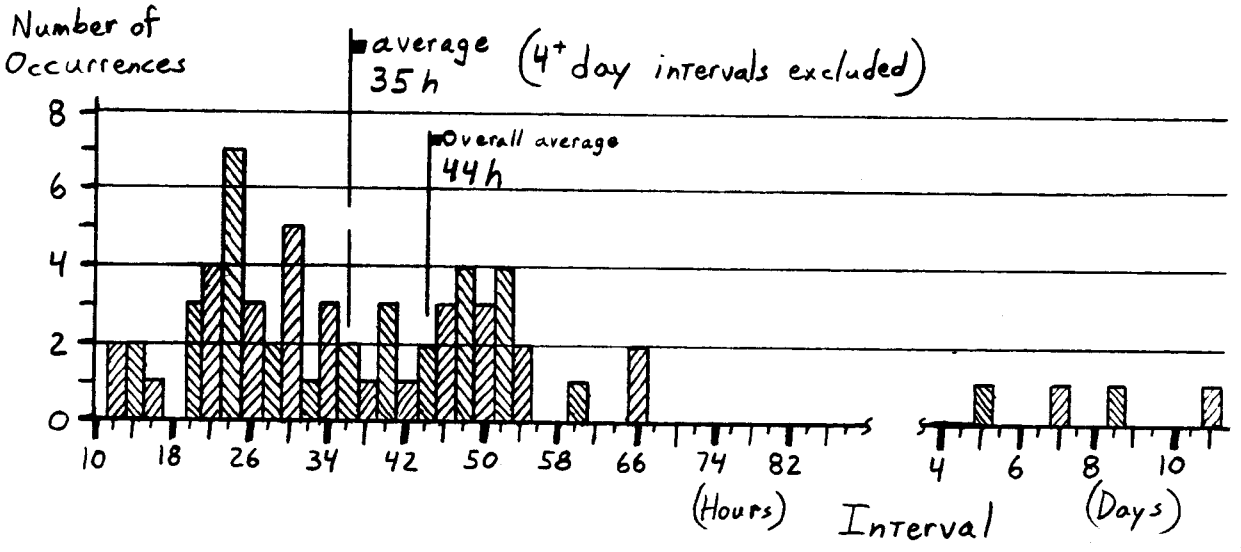
Grotto Long Duration (Marathon) Eruption Intervals

August 11 - October 30, 1988



Giant Hot Period (Major) Intervals

June 28 - October 30, 1988



Giant Hot Periods

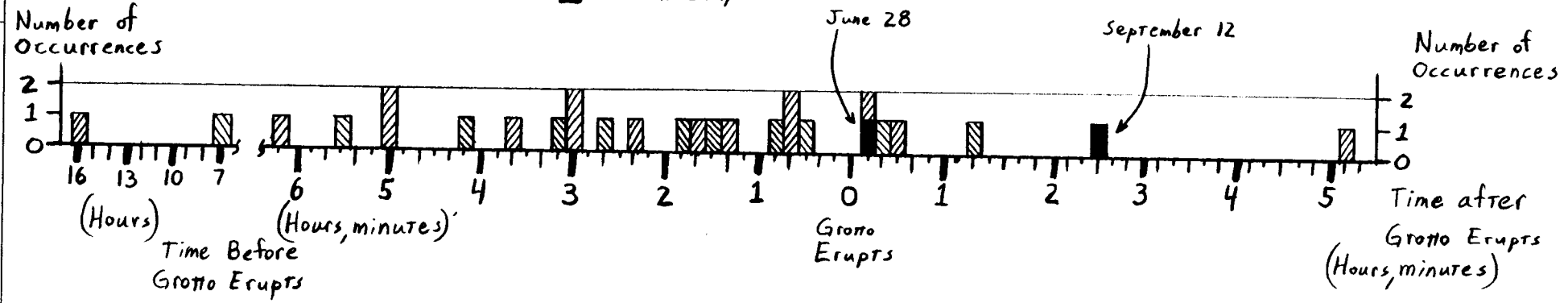
June 28 - October 30, 1988

Graph of observed Hot Periods and Grotto Eruption (Start Ups) Only.

Giant Hot Periods vs. Start of Any Grotto Eruption

▨, ▧ = Hot Period (Major Hot Periods Only)

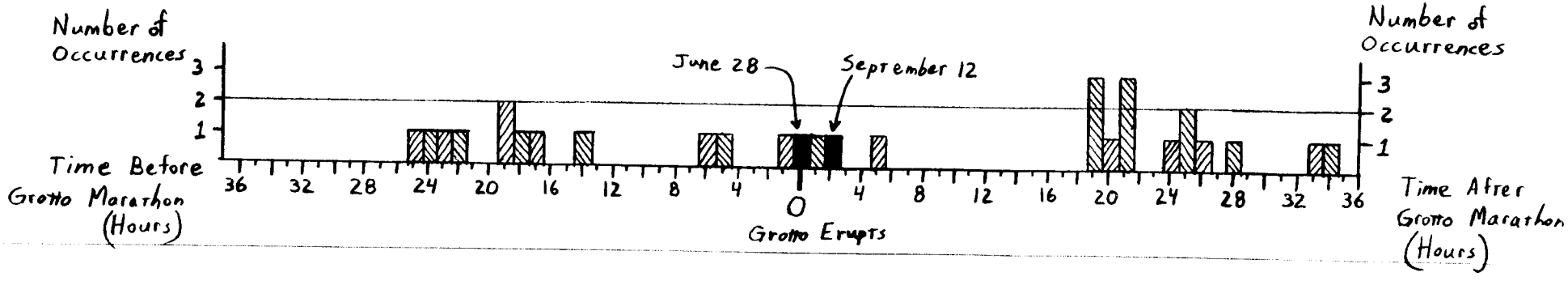
■ = Giant Eruption



Giant Hot Periods vs. Start of Grotto Marathon (Long Duration) Eruption

▨, ▧ = Hot Period (major hot periods only)

■ = Giant Eruption



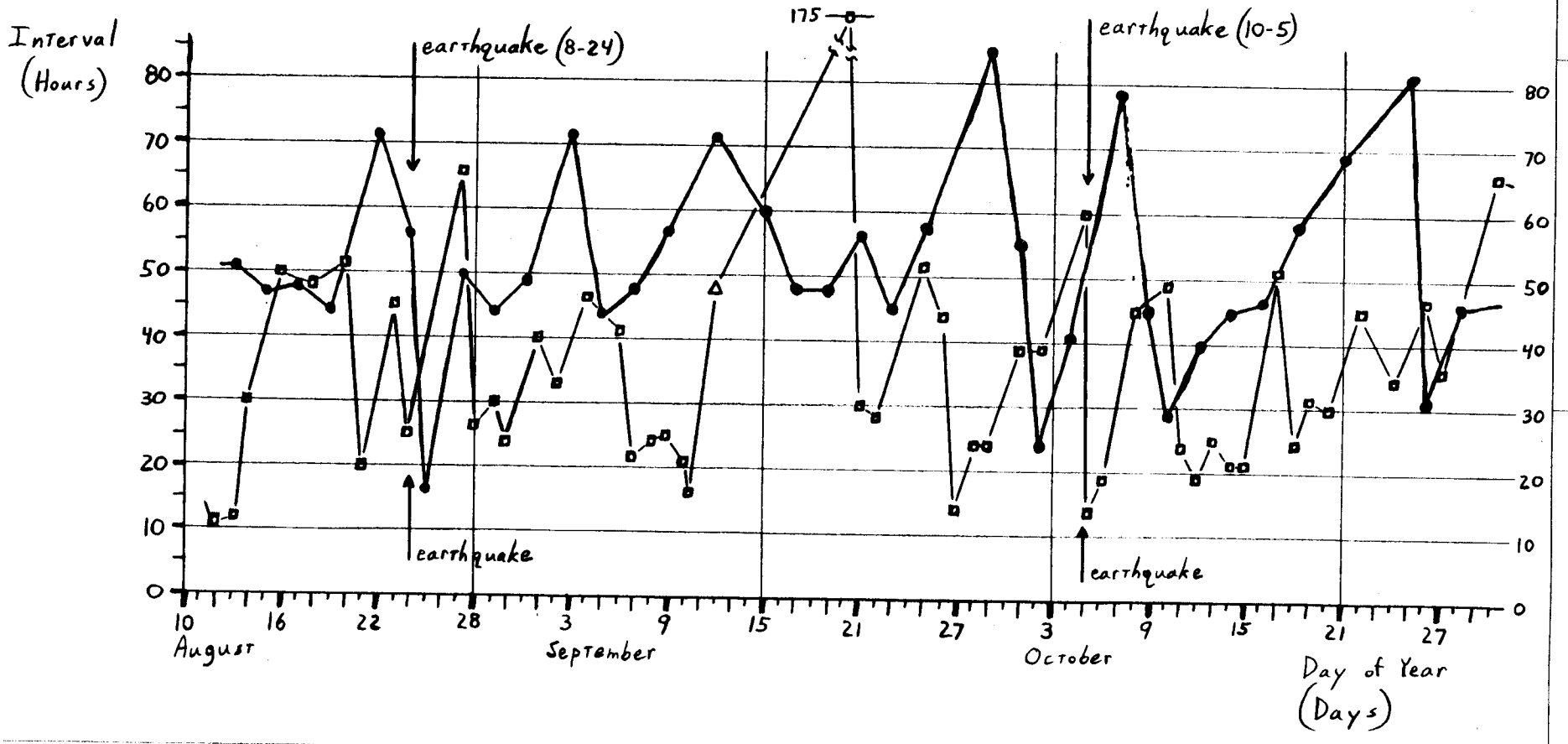
Giant + Grotto Activity

August 10 - October 30, 1988

● = Grotto Long Duration Eruption (Marathon)

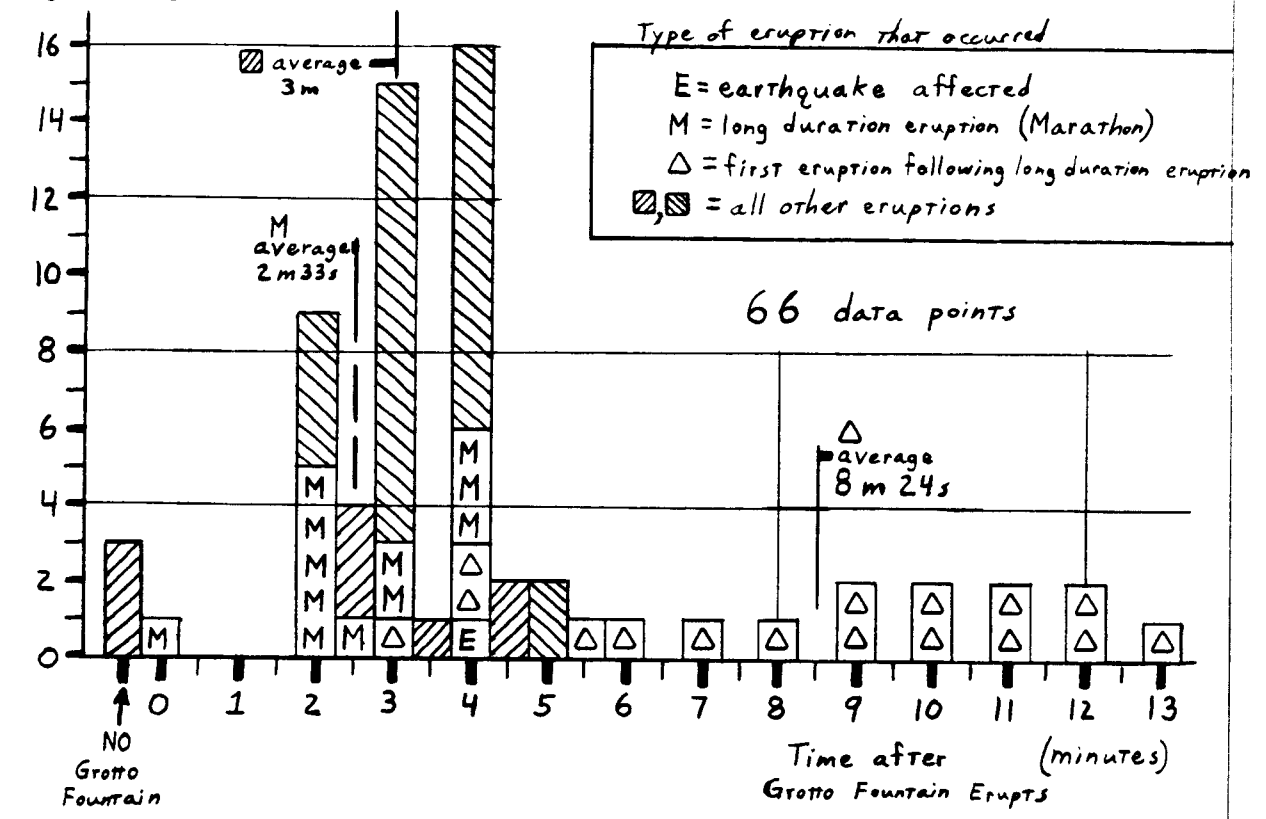
□ = Giant Hot Period (major)

Δ = Giant eruption (9-12)



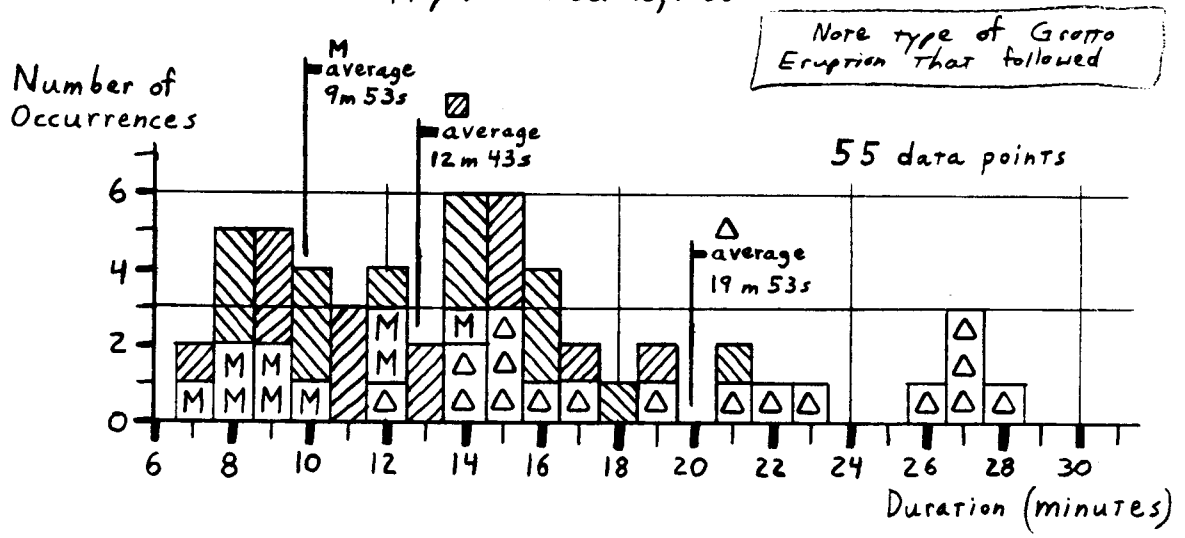
Time Grotto Geyser eruption begins after Grotto Fountain erupts

May 1 - October 16, 1988



Grotto Fountain Eruption Duration

May 1 - October 16, 1988

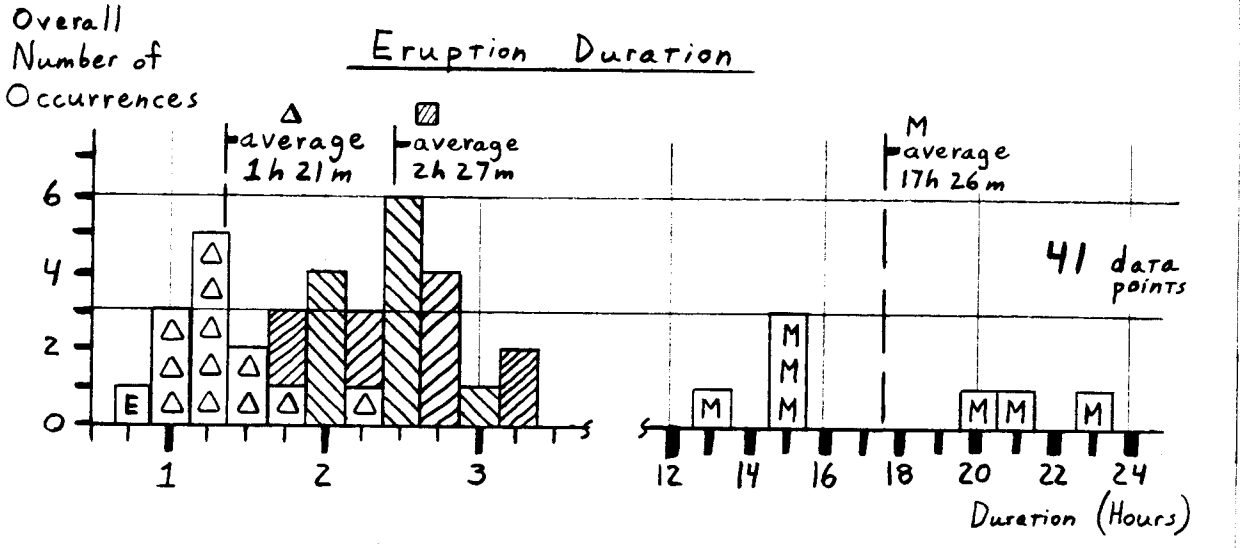


Grotto Geyser

May 1 - October 16, 1988

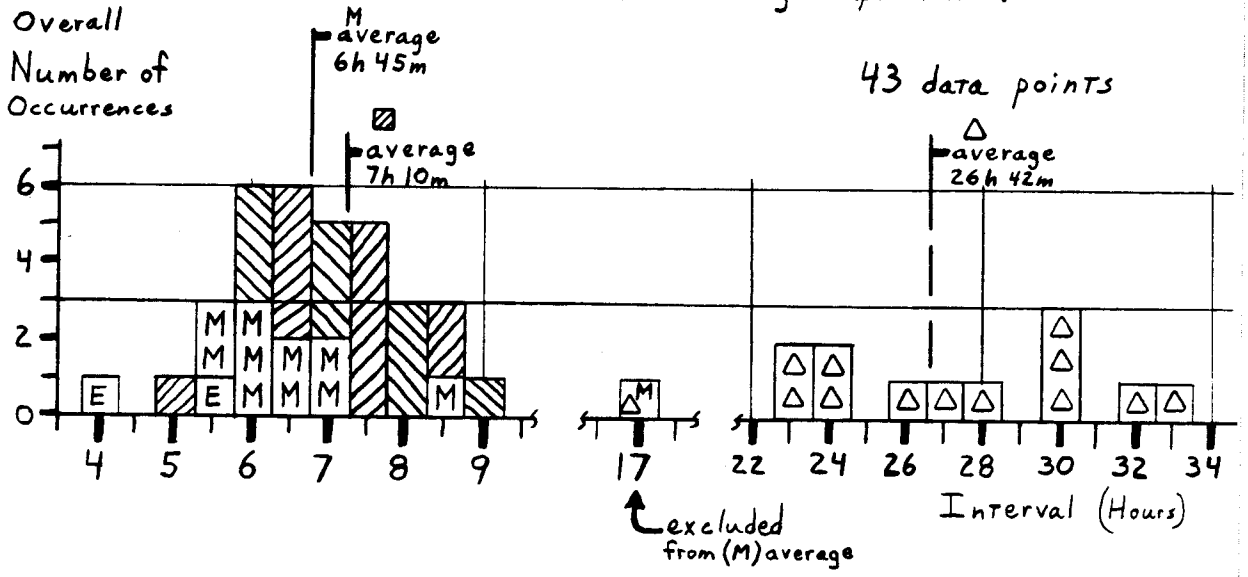
E = earthquake affected (August 24)
M = long duration eruption (Marathon)
△ = first eruption following long duration eruption
▨, ▧ = all other eruptions

Eruption Duration



Eruption Interval

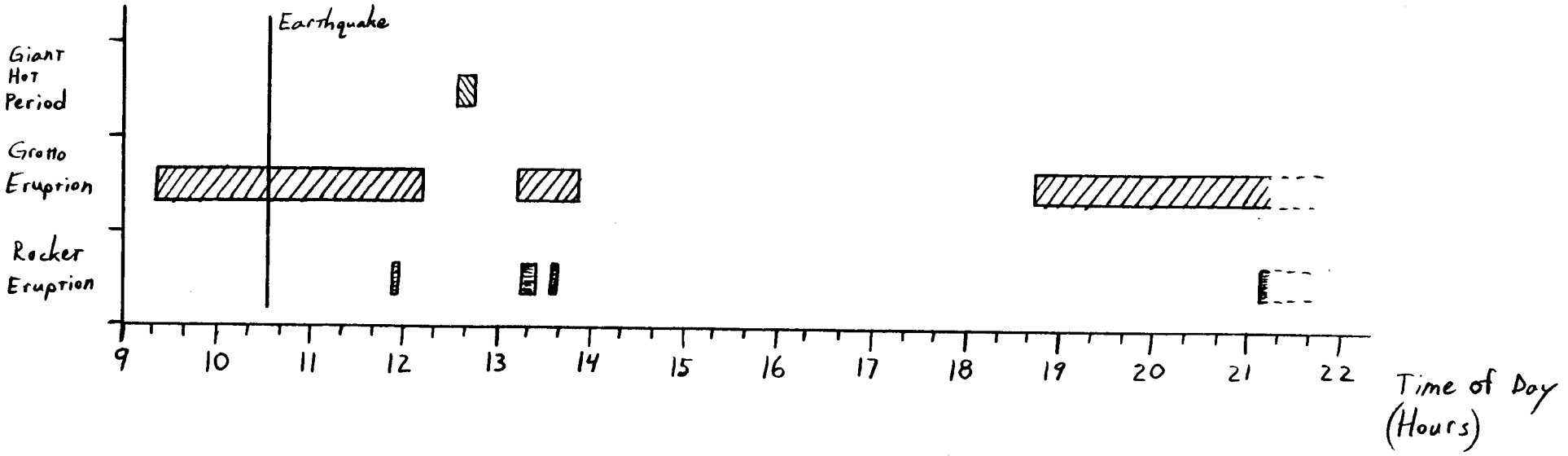
Note: Interval ends with the following eruption form.



Effect of August 24 earthquake on the Grotto/Giant Area

Earthquake located near Lone Star Geyser

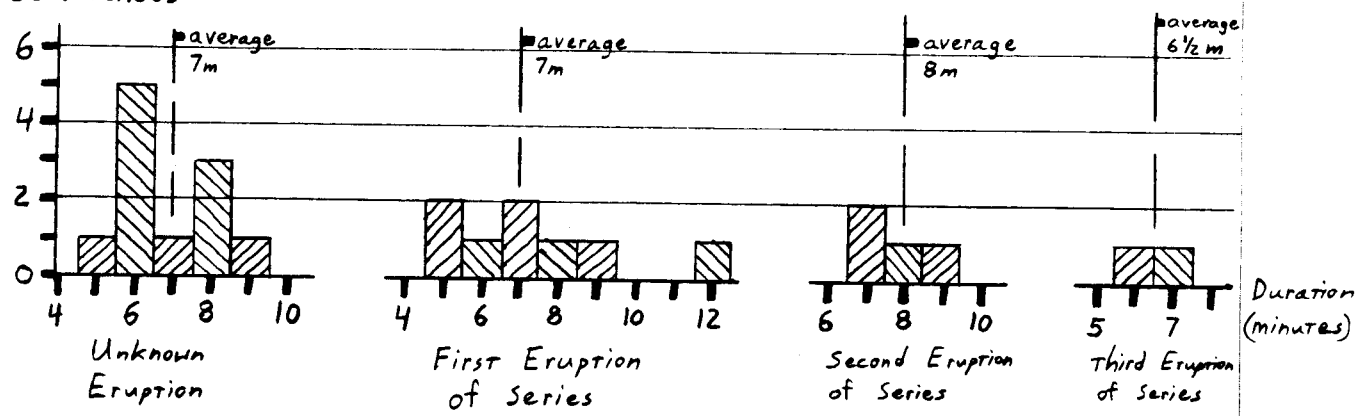
Intensity 2.5 R
shallow depth 2-5 km, mostly 2 km
5 tremors - 4 quick, then a pause and the 5th tremor



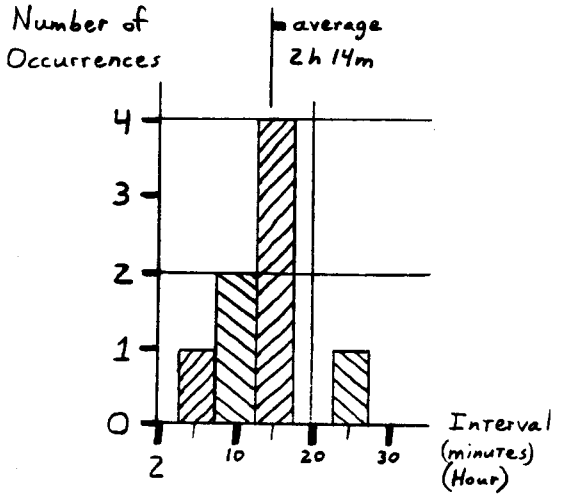
Oblong Geyser

May 1 – October 11, 1988

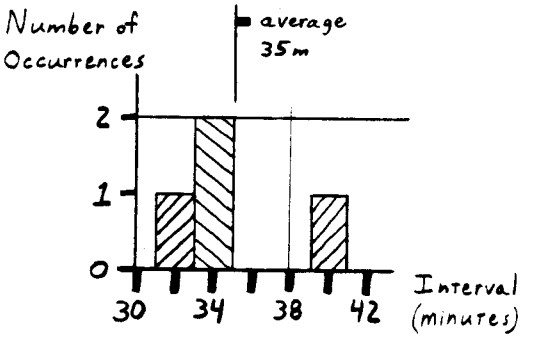
Eruption Duration



Eruption Interval Between First and Second Eruption of Series

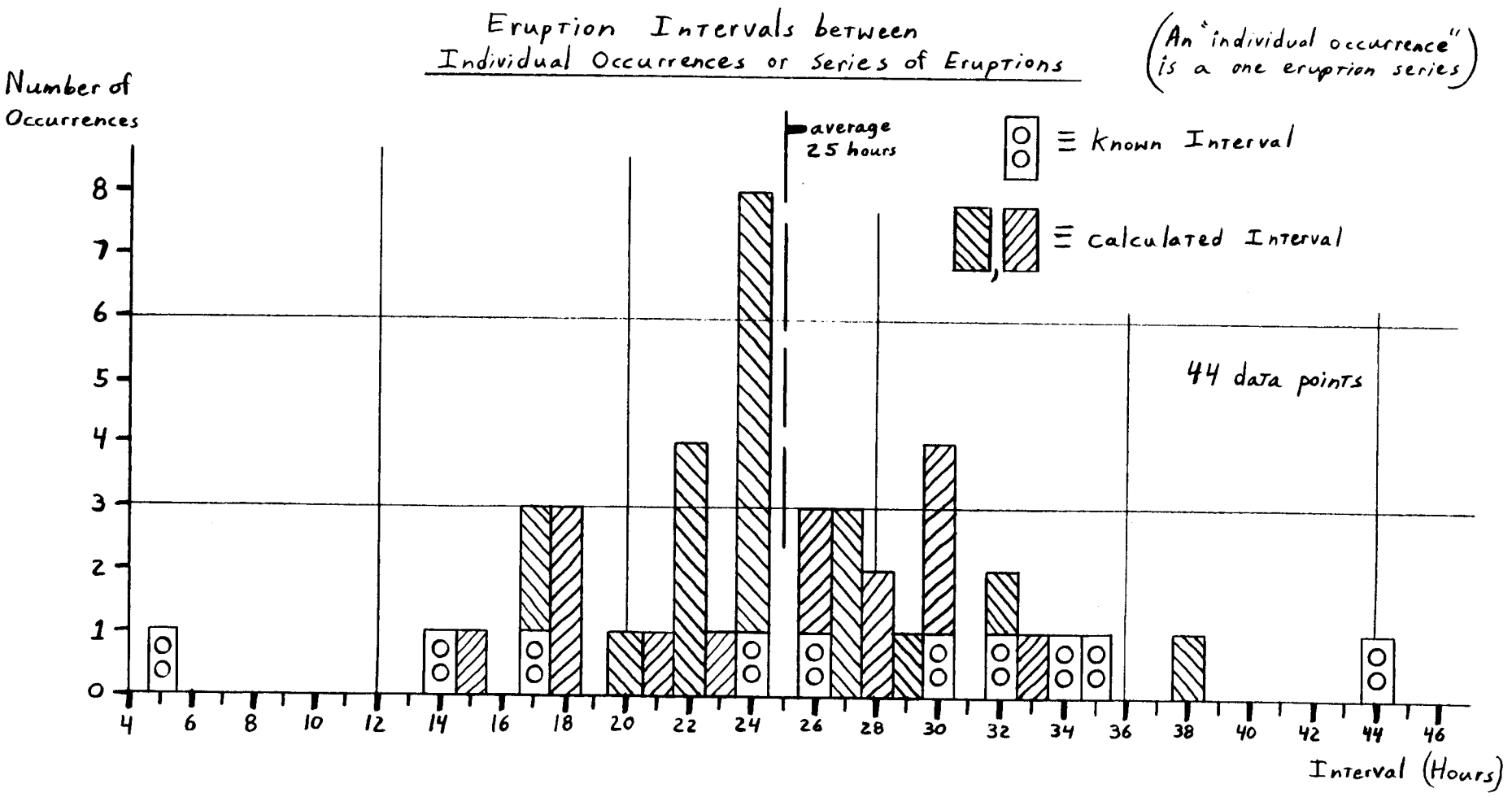


Eruption Interval Between Second and third eruption of Series



Oblong Geyser

May 1 - October 11, 1988



Rocket Geyser

May 1 – October 18, 1988

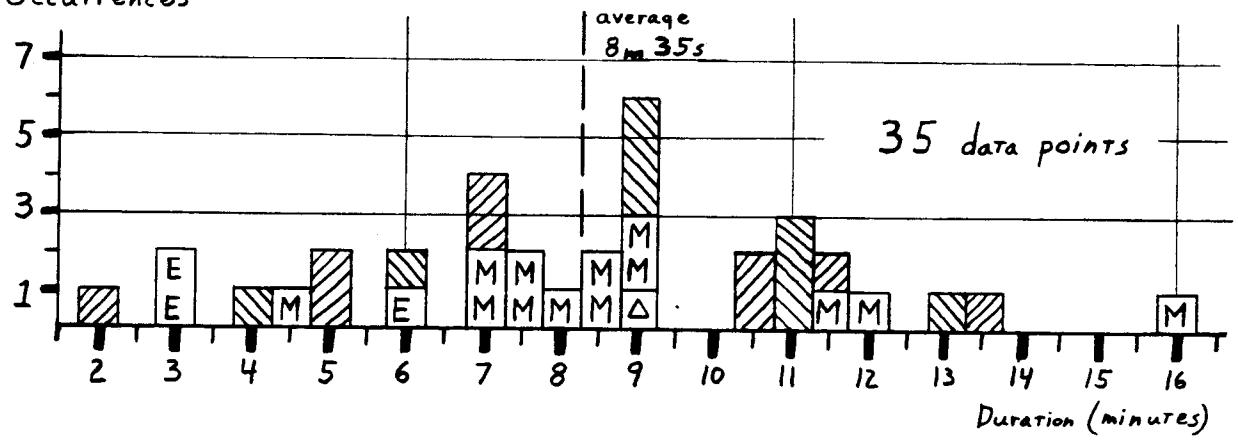
E = earthquake affected (August 24)

M = long duration Grotto Eruption (Marathon)

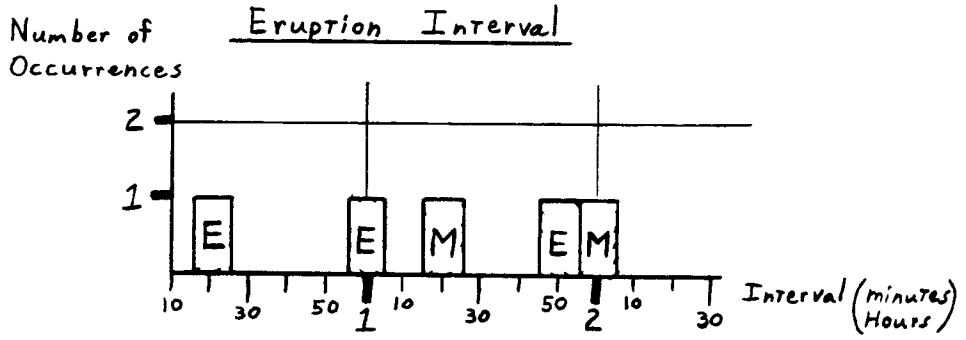
△ = First Grotto Eruption following long duration eruption

▨, ▧ = Rocket erupts during Grotto eruption of 2-3 hours duration

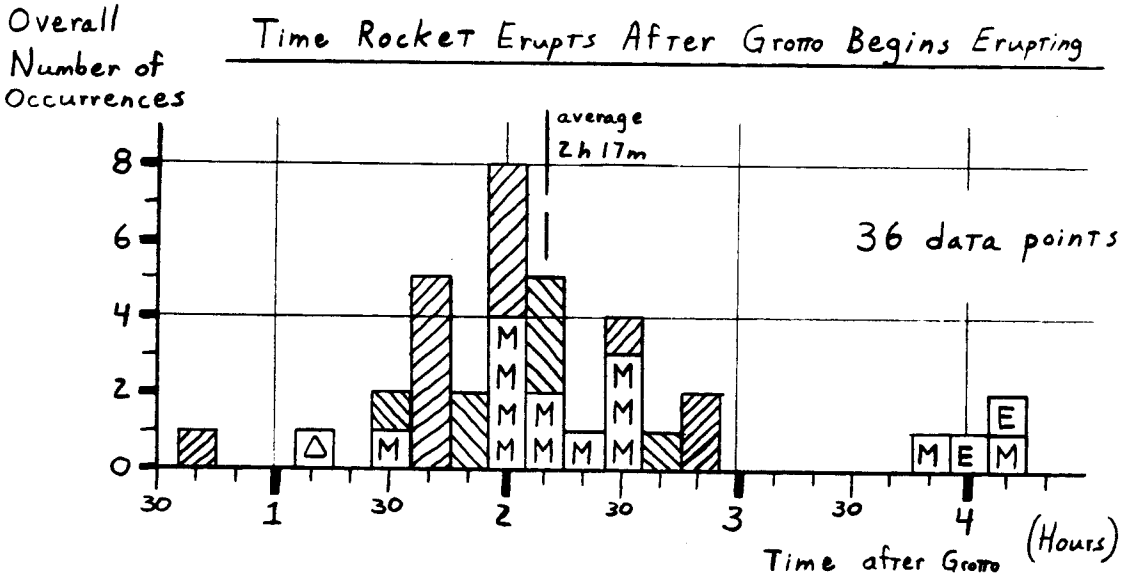
Eruption Duration



Eruption Interval



Time Rocket Erupts After Grotto Begins Erupting

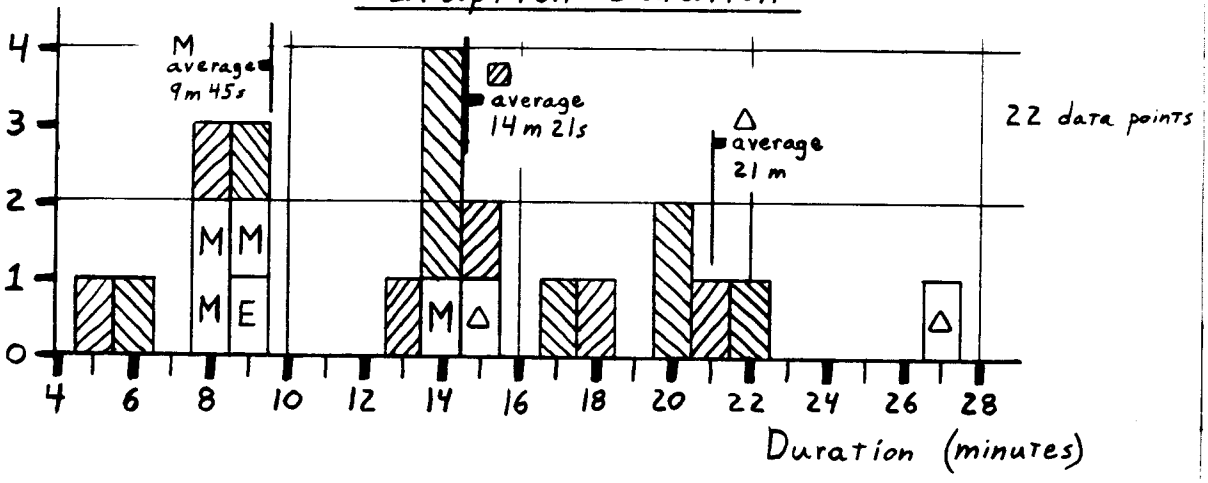


South Grotto Fountain

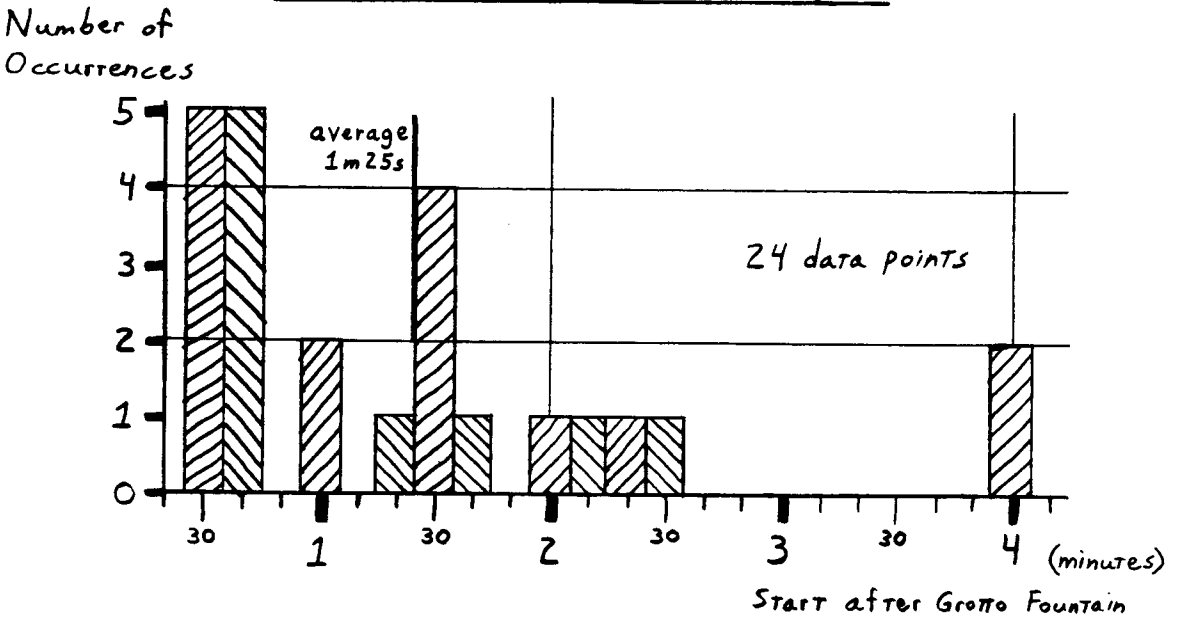
May 1 - October 16, 1988

E = earthquake affected
M = start of long duration Grotto Eruption (Marathon)
△ = first Grotto eruption following long duration Grotto eruption
▨, ▧ = all other Grotto eruptions

Eruption Duration



Time South Grotto Fountain Erupts After Grotto Fountain Begins Erupting

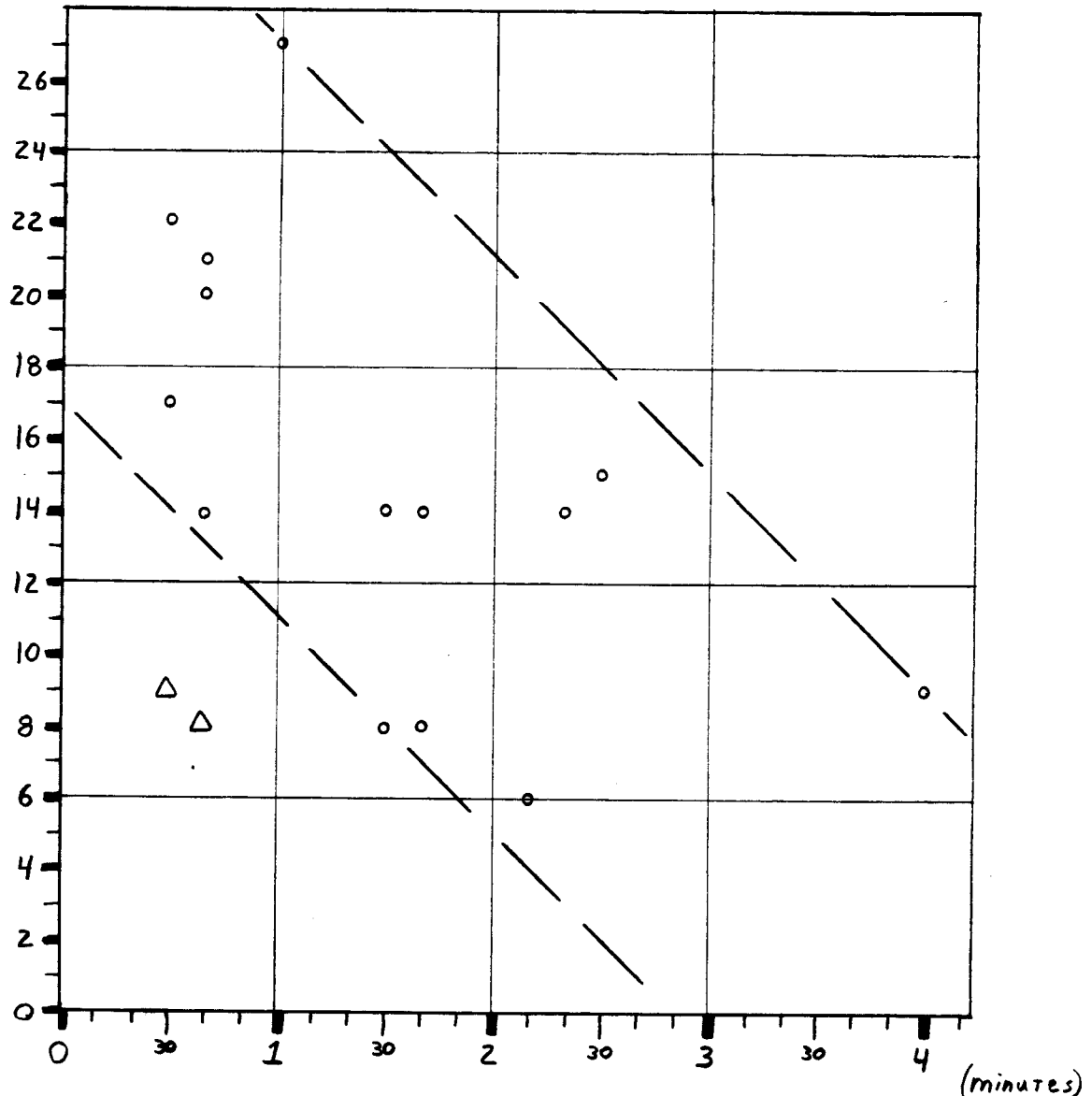


South Grotto Fountain

May 1 - October 16, 1988

South Grotto Fountain
Eruption Duration

o = May 1 - August 23
Δ = after August 24 earthquake
(August 25 - October 16)

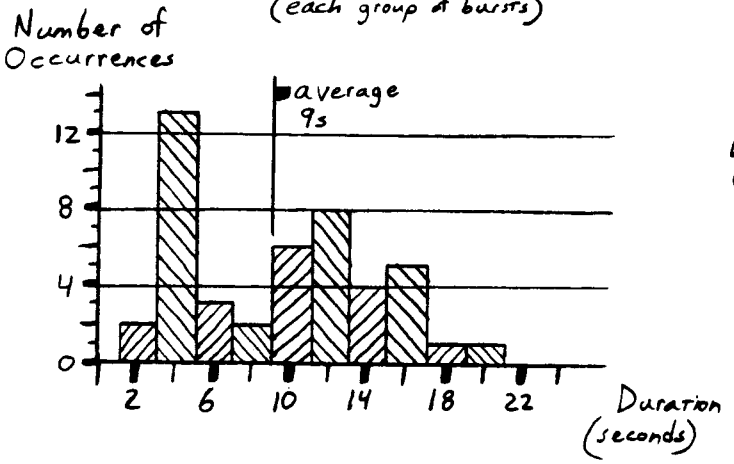


Time South Grotto Fountain Erupts
After
Grotto Fountain Begins erupting

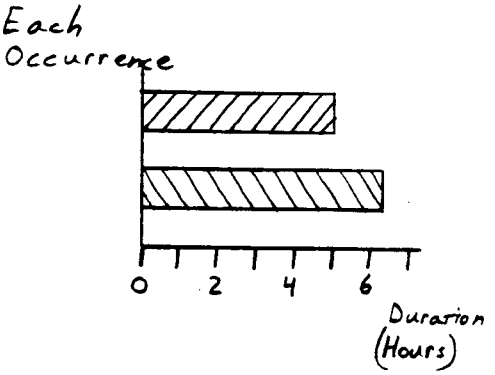
SPA Geyser

May - October, 1988

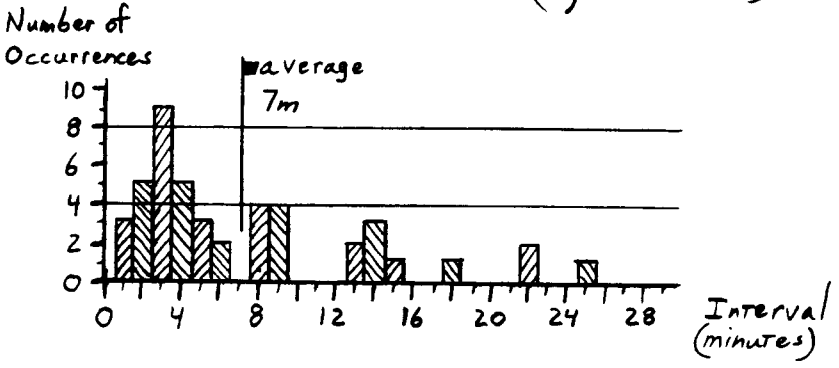
Eruption Duration
(each group of bursts)



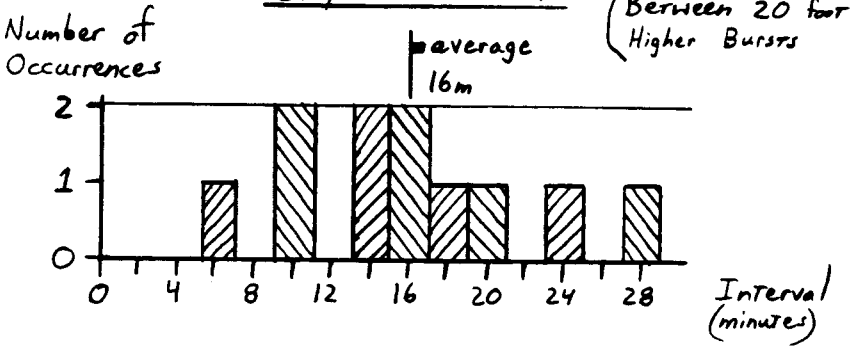
Eruption Series Duration



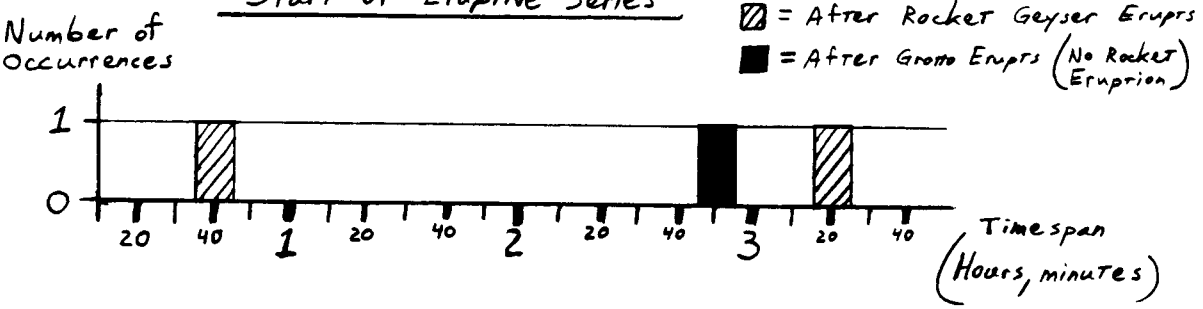
Eruption Interval
(Between 6 foot or Higher Bursts)



Eruption Interval
(Between 20 foot or Higher Bursts)



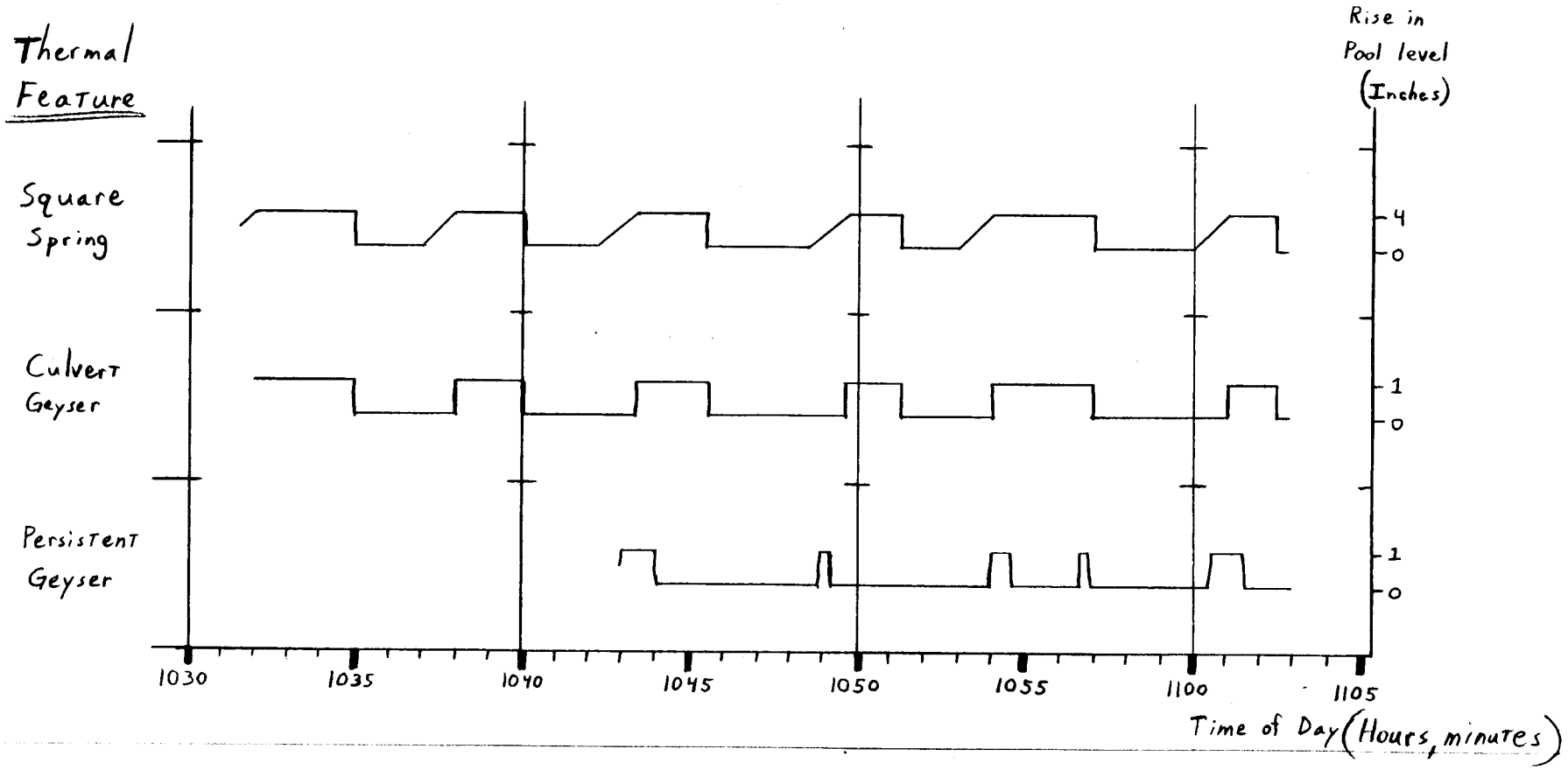
Start of Eruptive Series

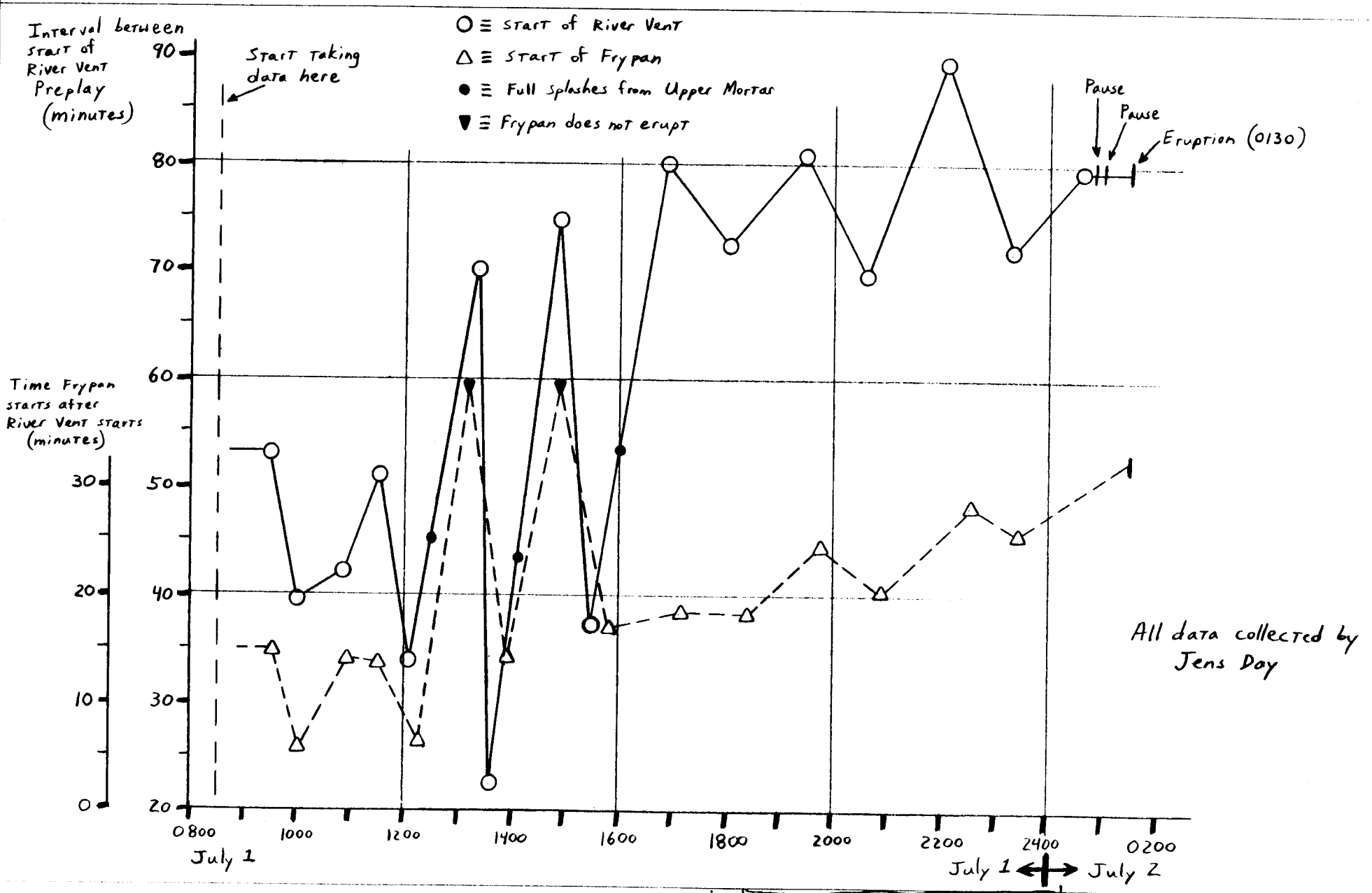


Relationship Between

Square Spring, Culvert Geyser, and Persistent Geyser

October 5, 1988



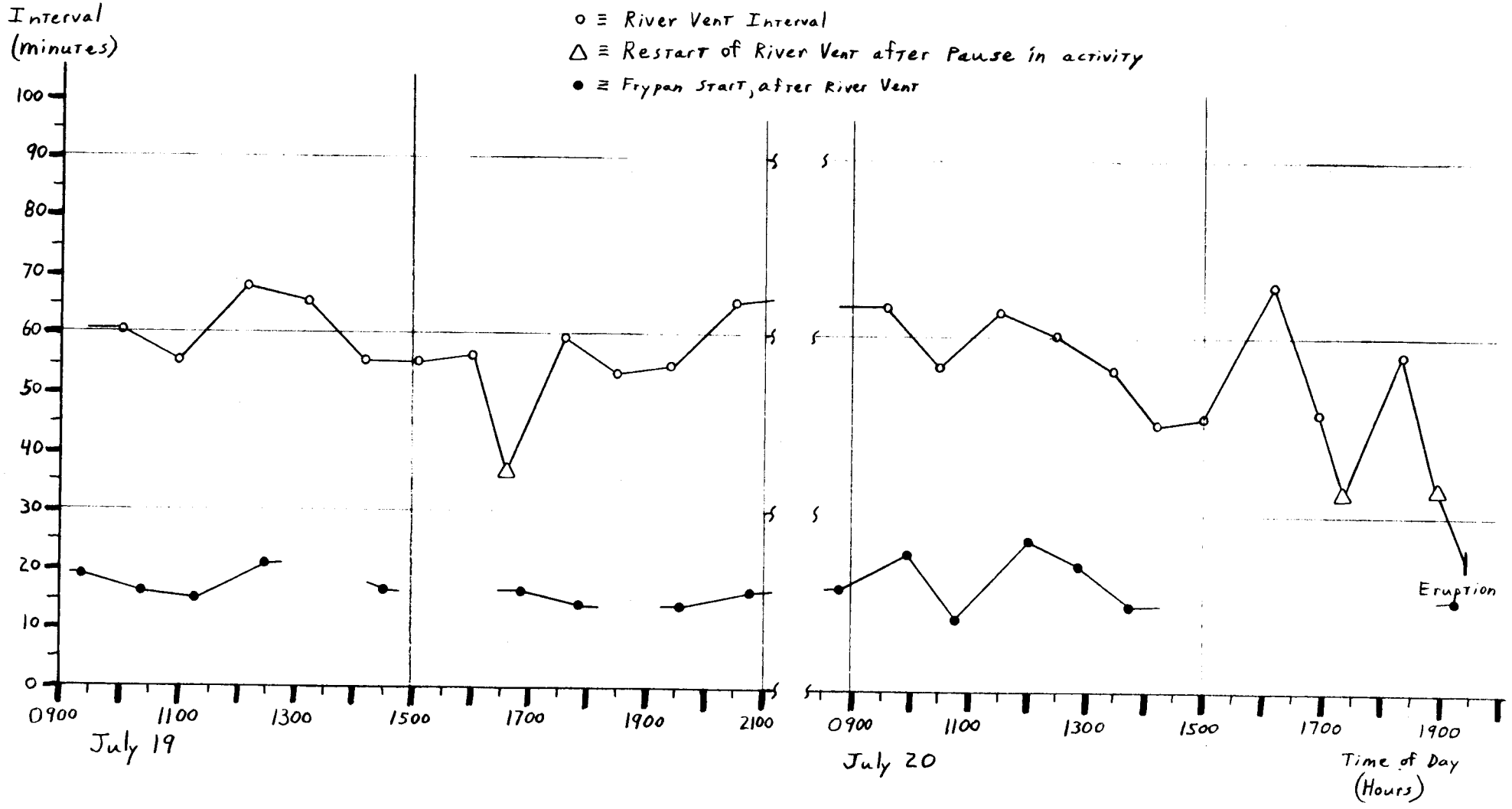


Fan + Mortar Geysers

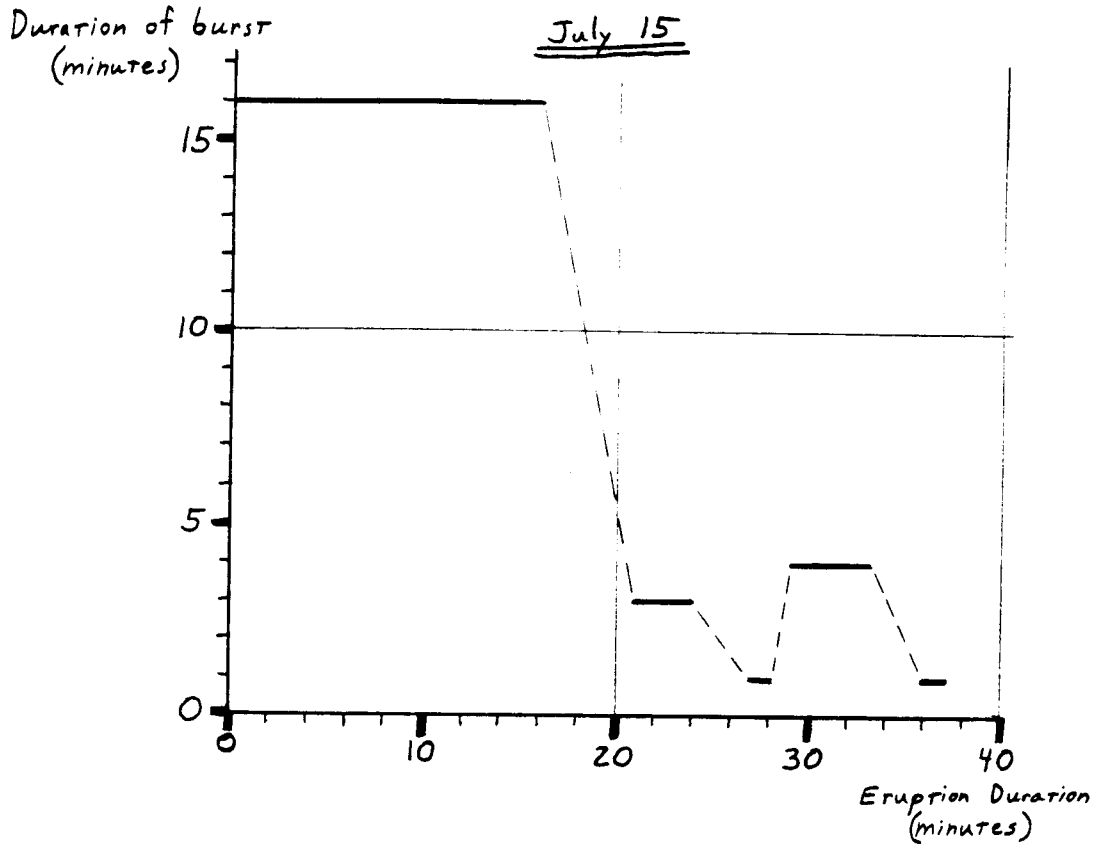
July 1-2 1988

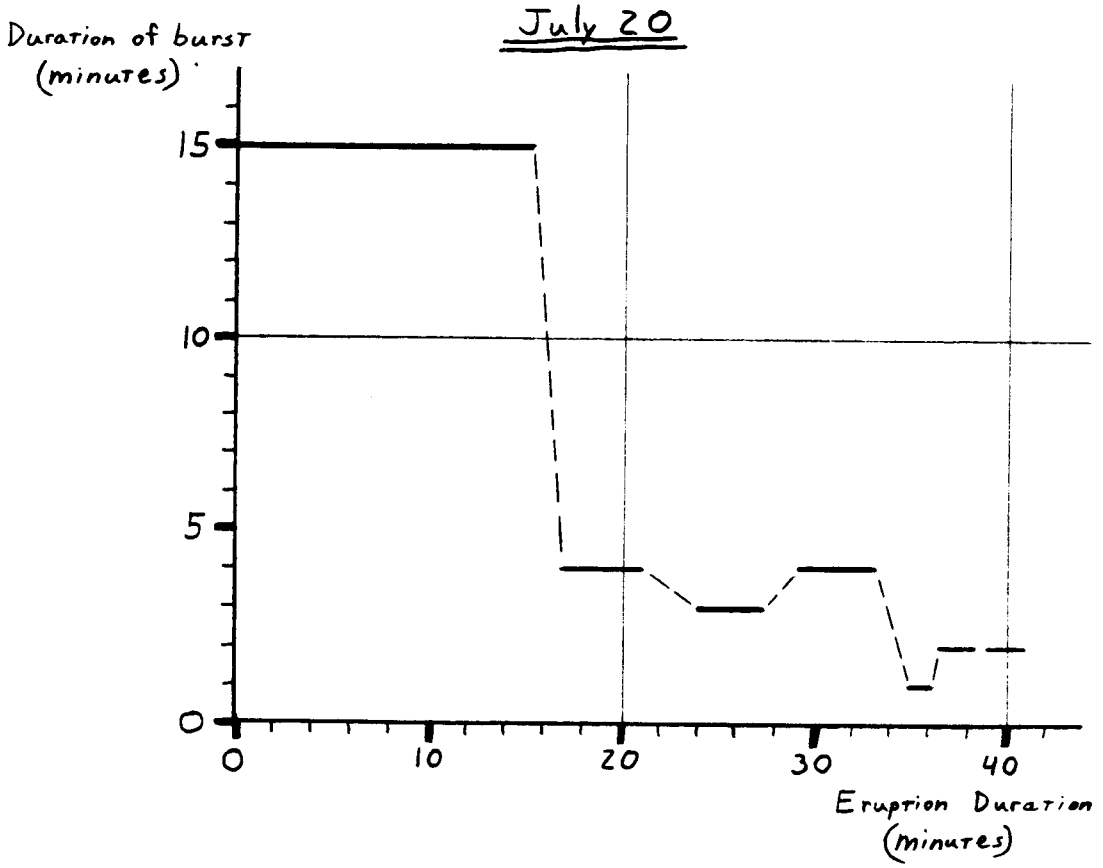
Fan + Mortar Geysers

July 19 + 20, 1988



Fan + Mortar Geysers

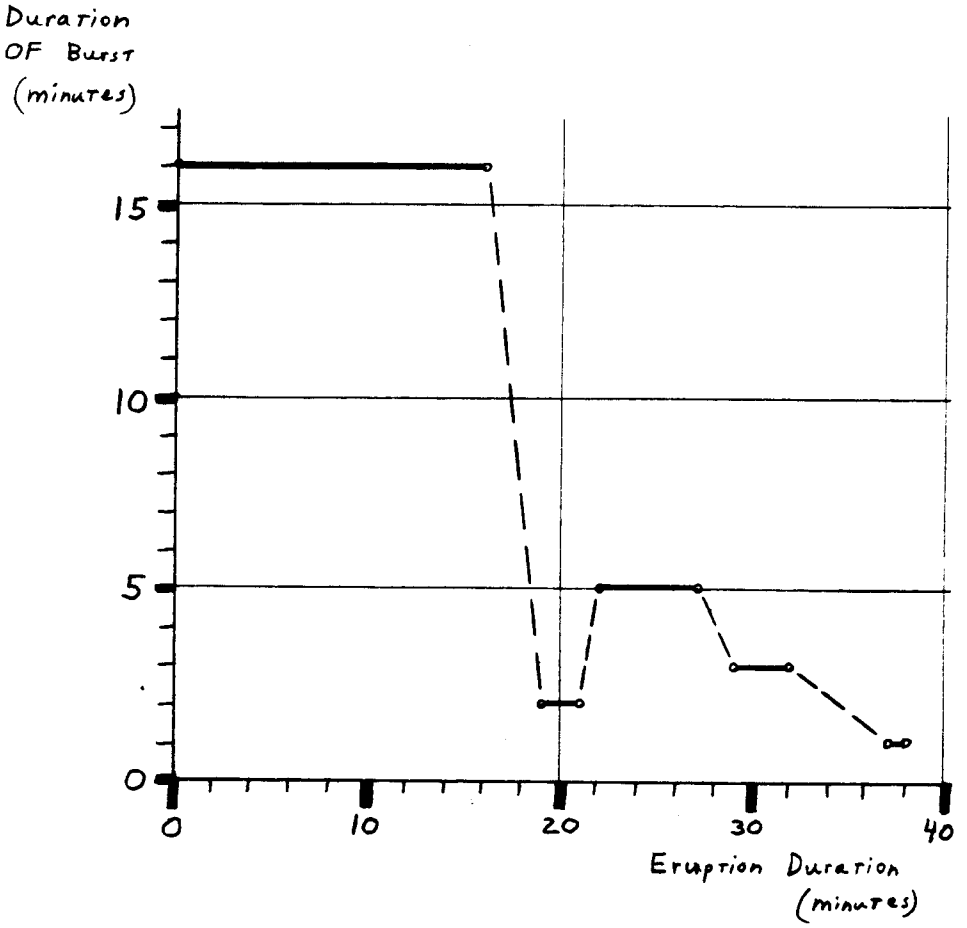


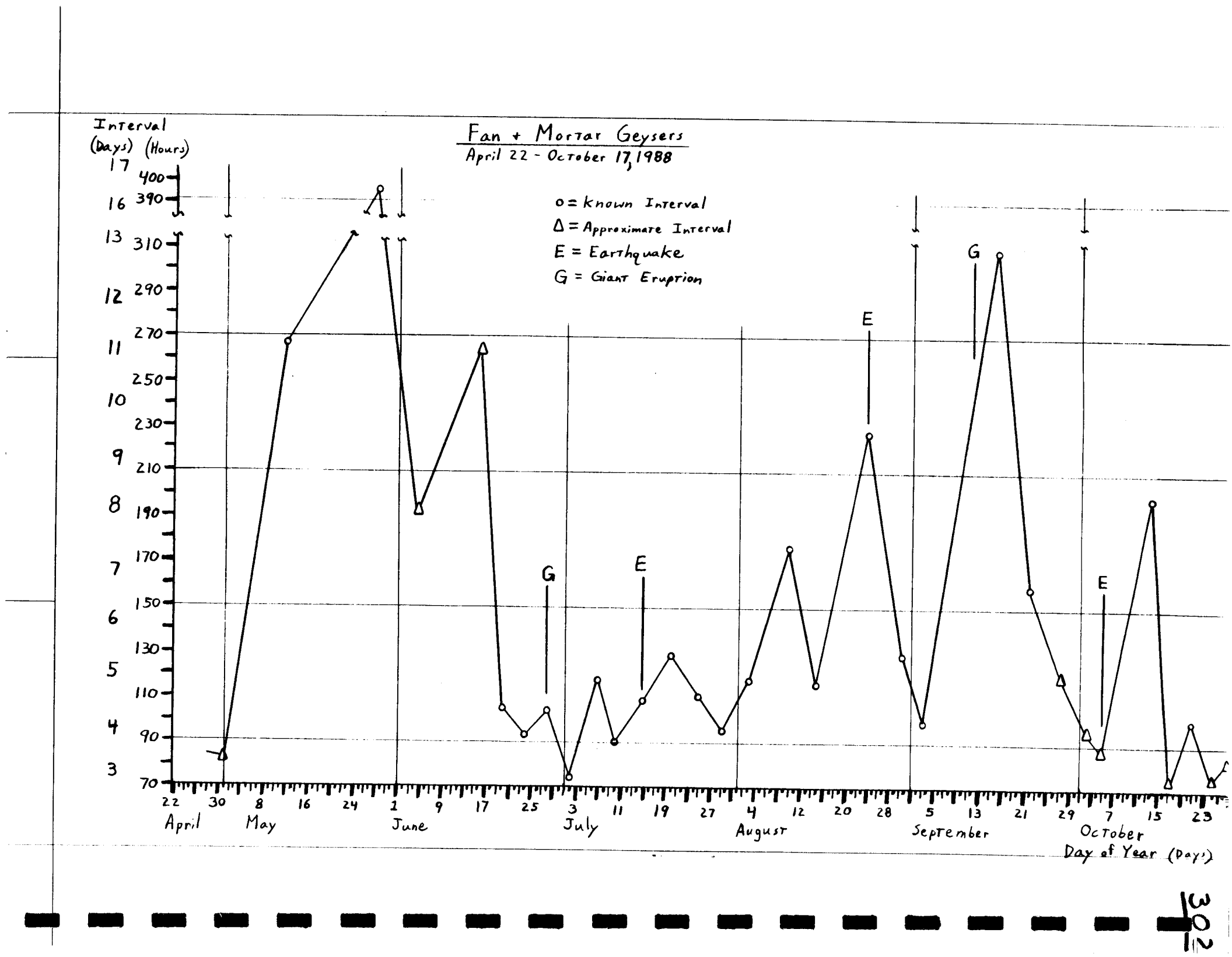


Fan + Mortar Geysers

October 21, 1988

All data collected by Jens Day

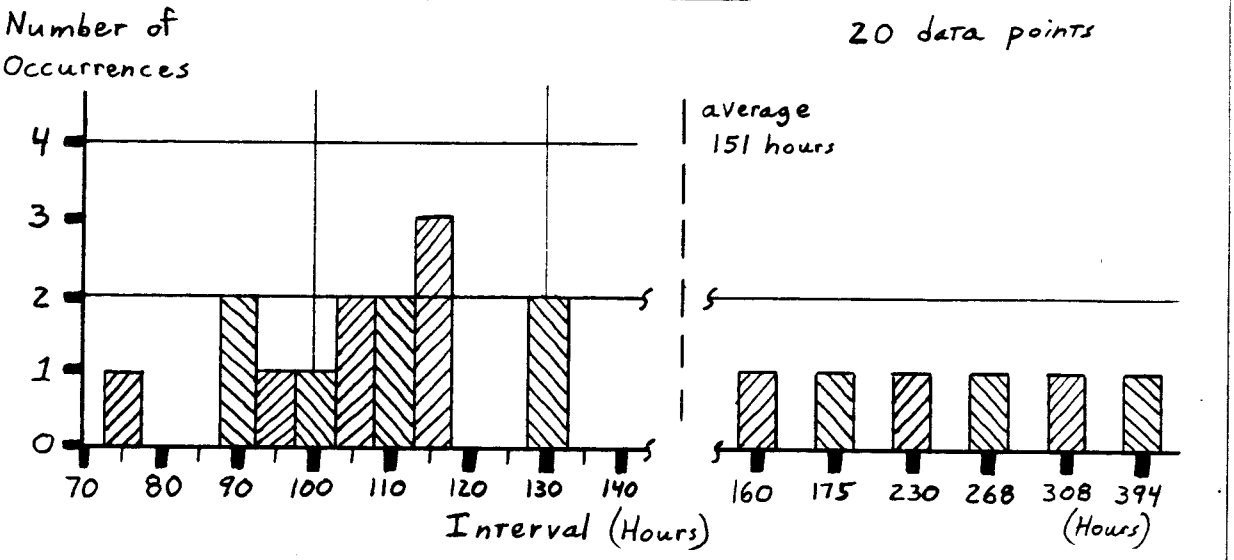



Fan + Mortar Geysers
April 22 - October 17, 1988
Interval (Days) (Hours)
o = known Interval
Δ = Approximate Interval
E = Earthquake
G = Giant Eruption
17 400
16 390
13 310
12 290
11 270
250
10 230
9 210
8 190
7 170
6 150
130
5 110
4 90
3 70
G
E
E
G
E
22 30 8 16 24 1 9 17 25 3 11 19 27 4 12 20 28 5 13 21 29 7 15 23
April May June July August September October
Day of Year (Days)

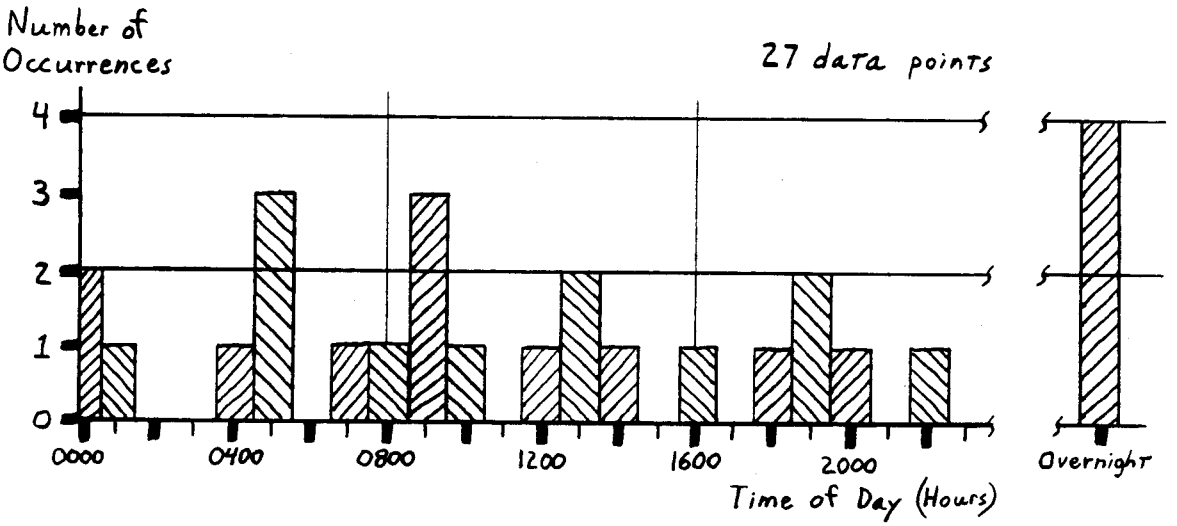
Fan + Mortar Geysers

May 1 - October 11, 1988

Eruption Intervals



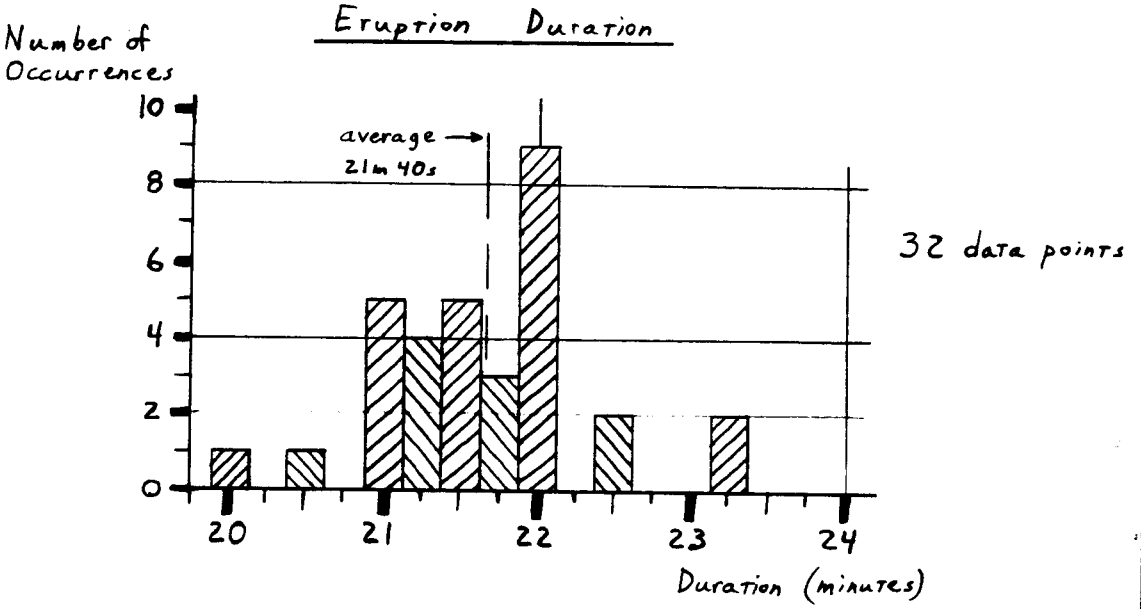
Eruption vs. Time of Day



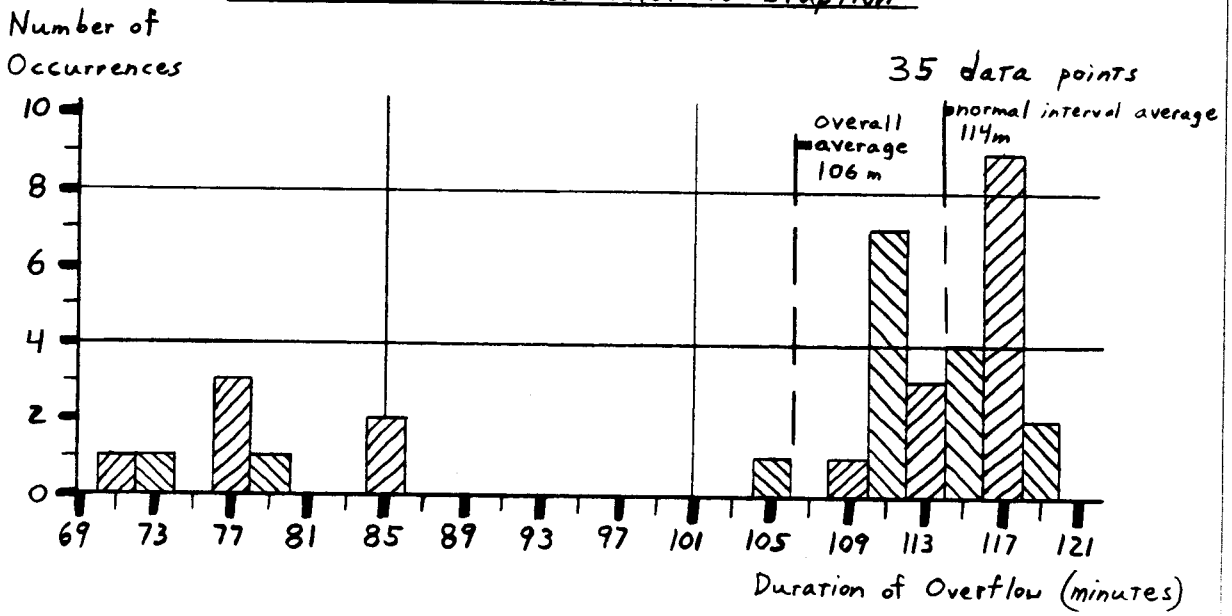
Riverside Geyser

May 2 - October 9, 1988

Eruption Duration

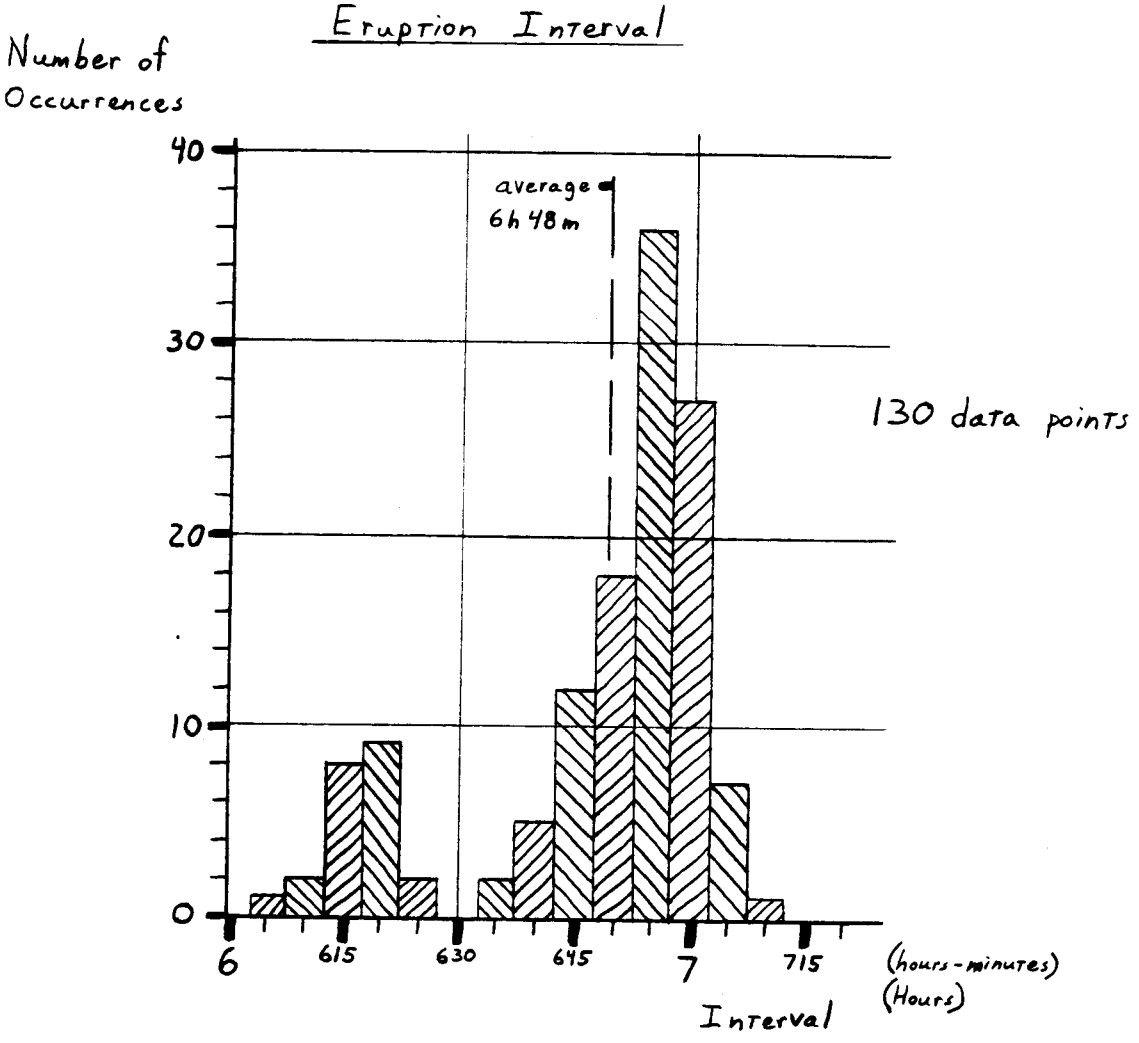


Duration of Overflow Prior to Eruption



Riverside Geyser

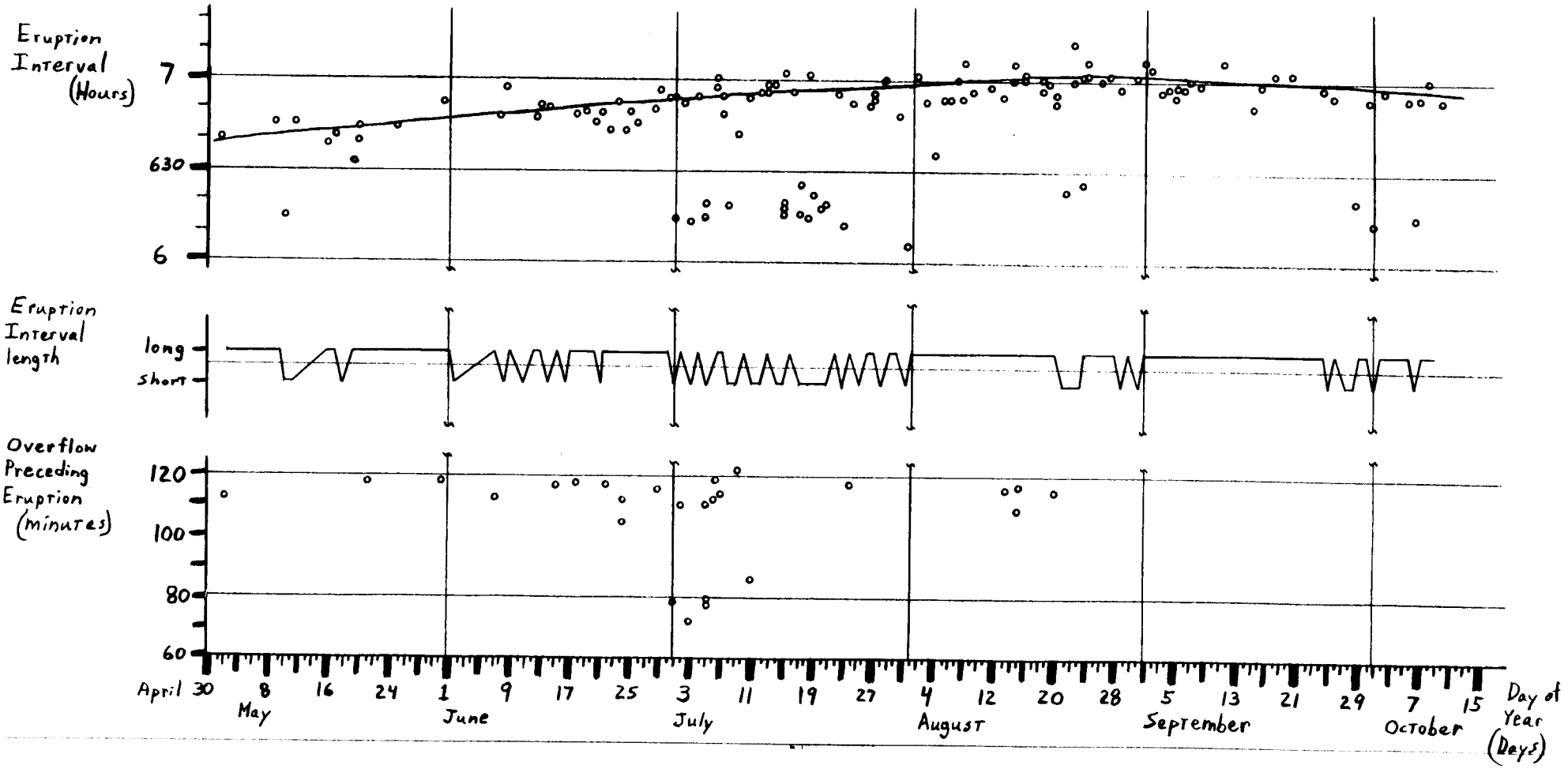
May 2 - October 9, 1988



Riverside Geyser

May 2 - October 9, 1988

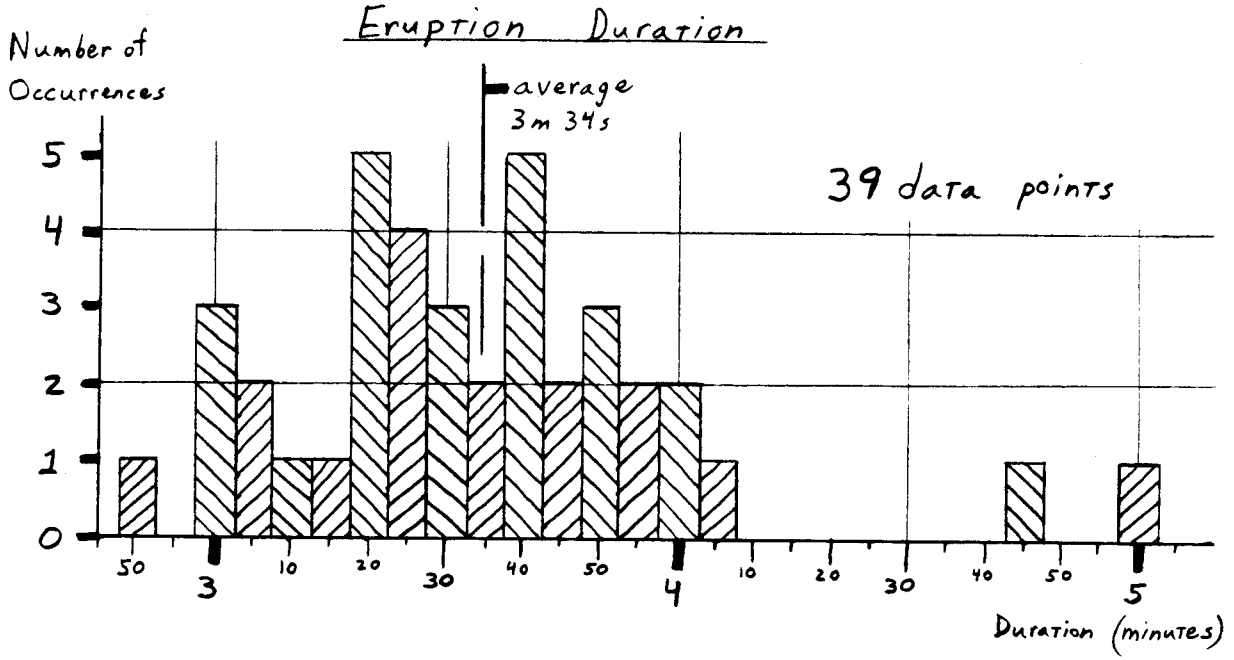
Eruption Interval and Overflow Preceding Eruptions



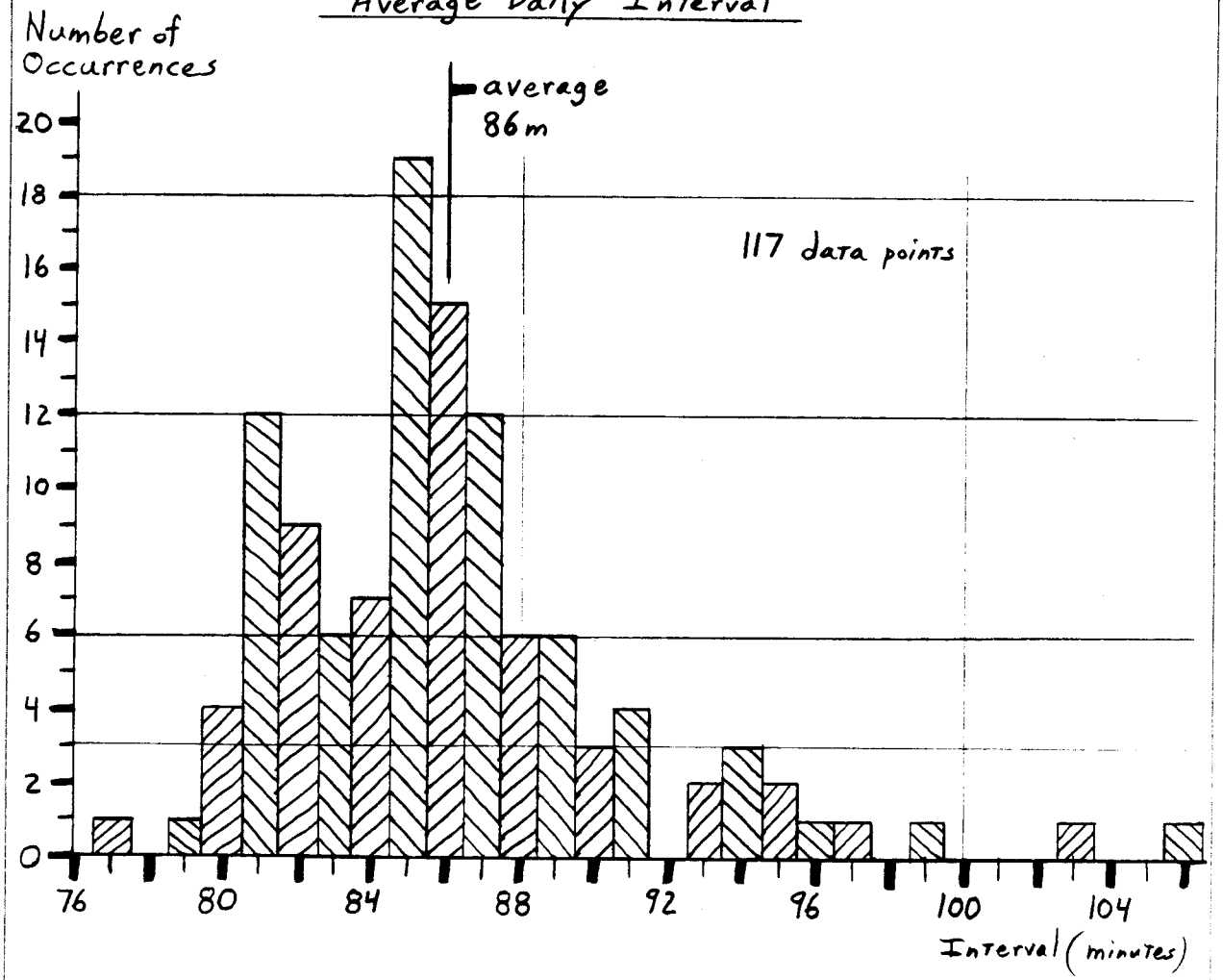
Daisy Geyser

May 2 - September 8, 1988

Eruption Duration



Average Daily Interval



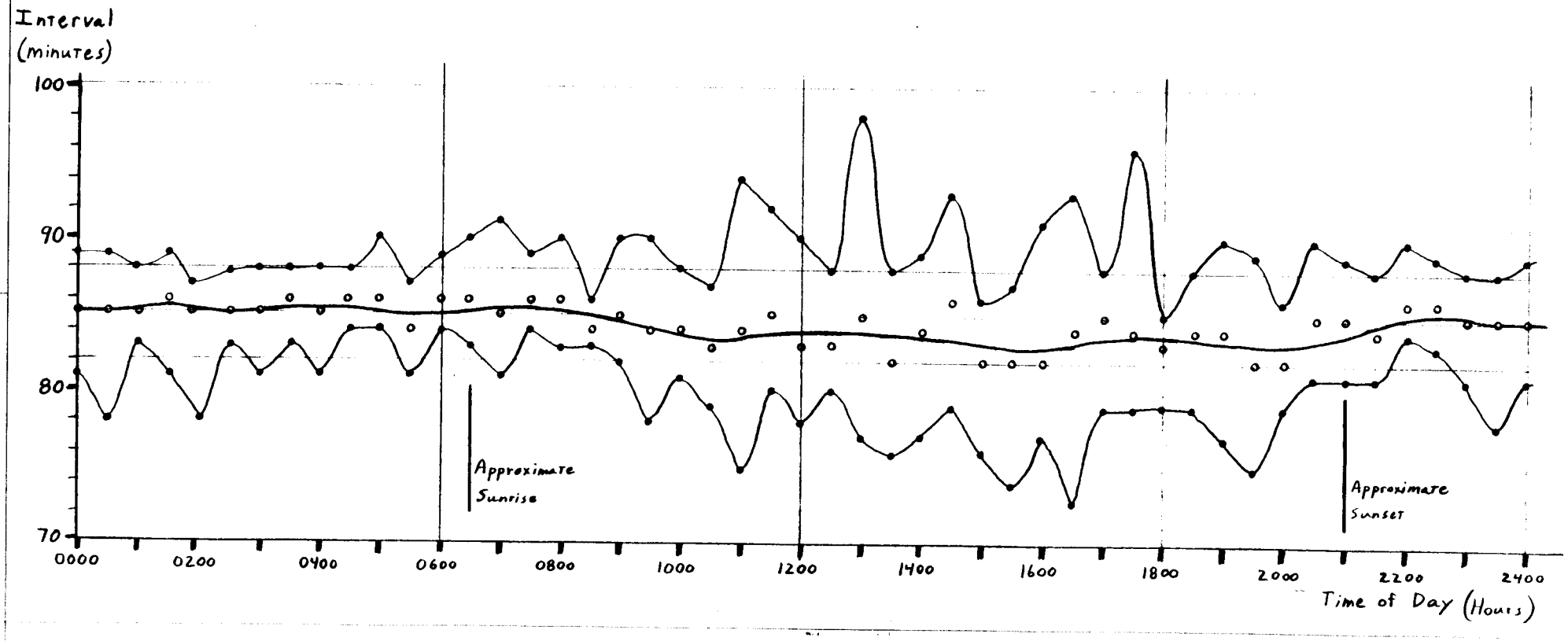
Daisy Geyser

August 3 - September 3, 1988

data compiled within ± 15 minutes for every data point

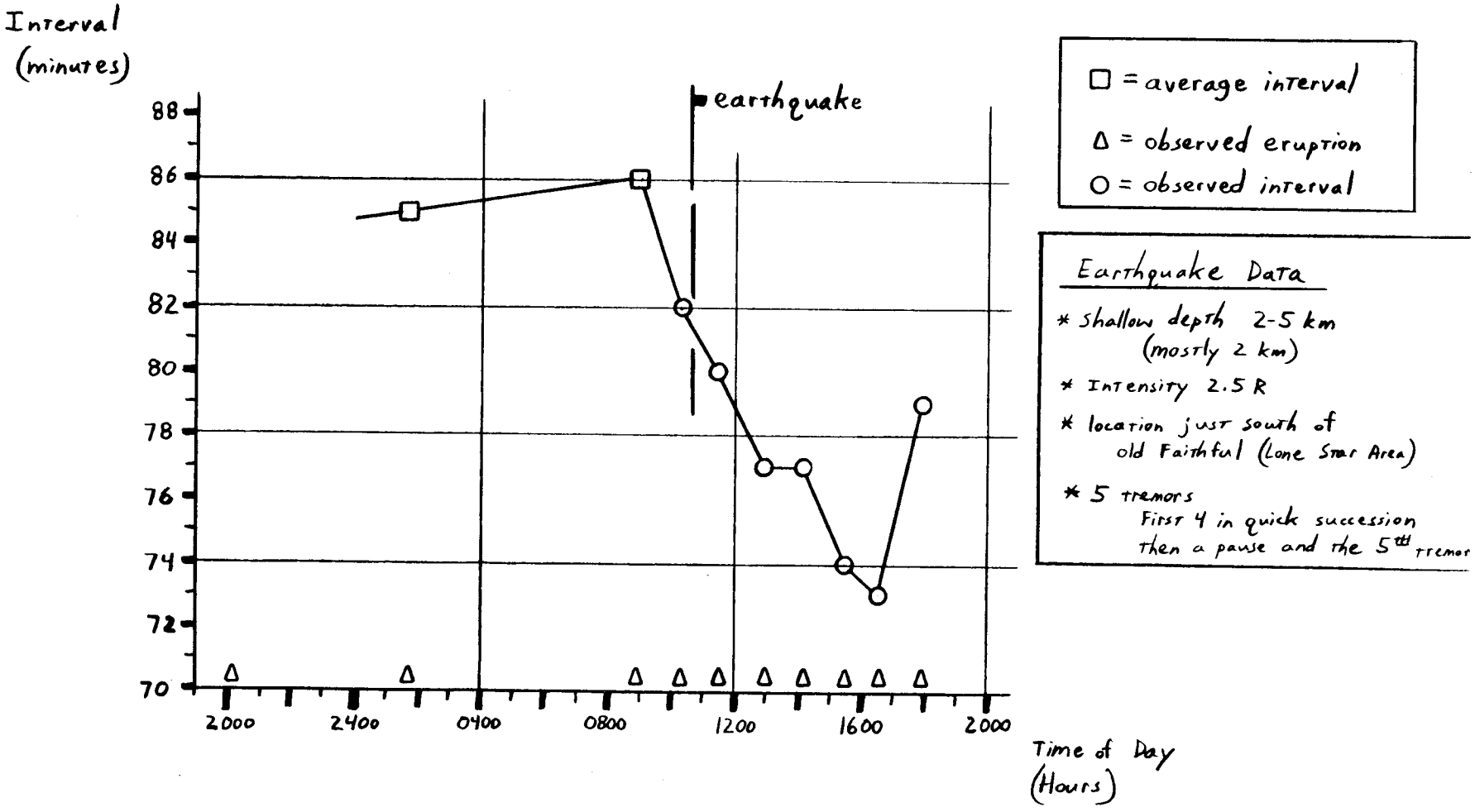
o ≡ average interval

• ≡ extreme data points



Daisy Geyser

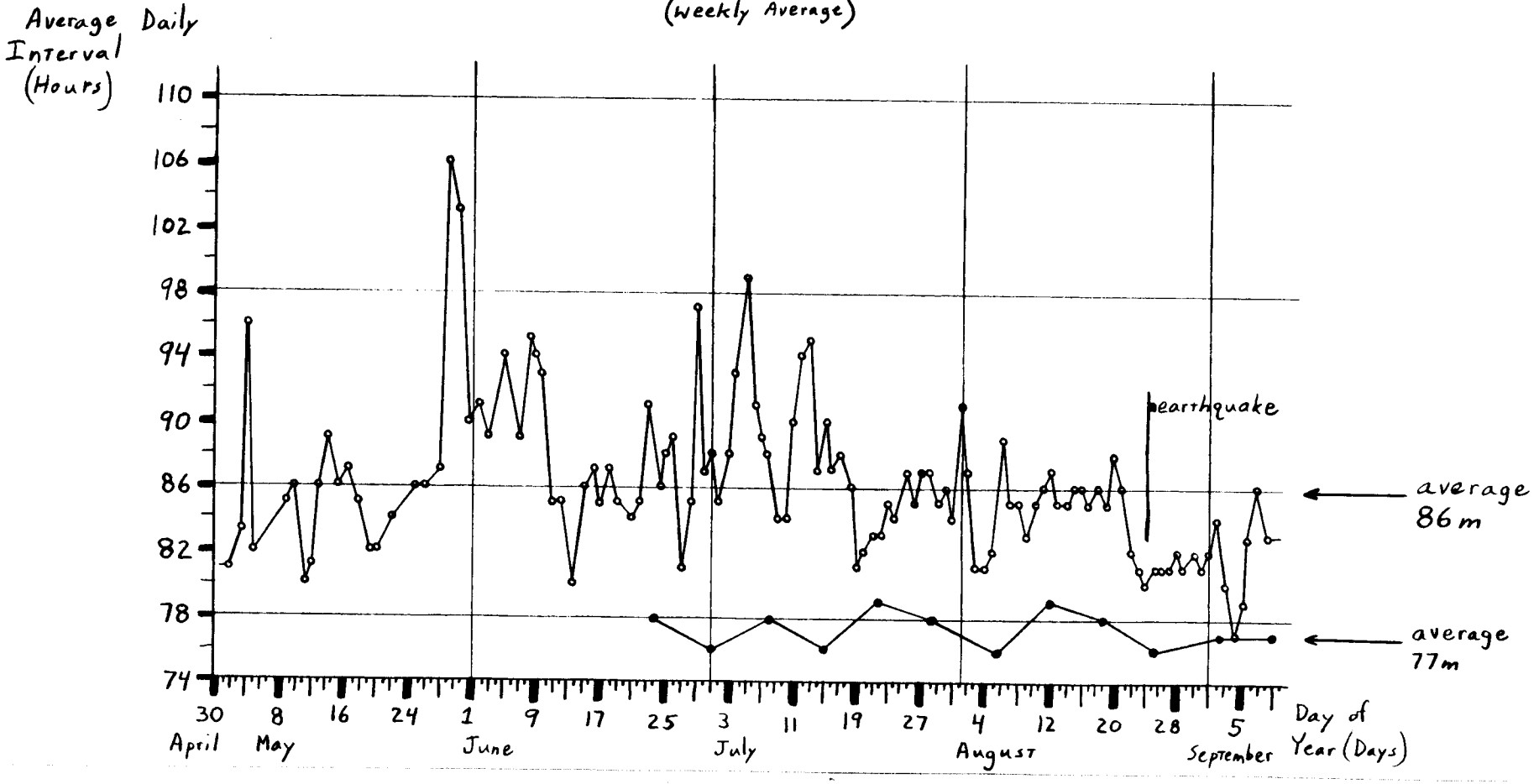
August 23 + 24, 1988



Daisy Geyser

o = May 2 - September 8, 1988
(Daily Average)

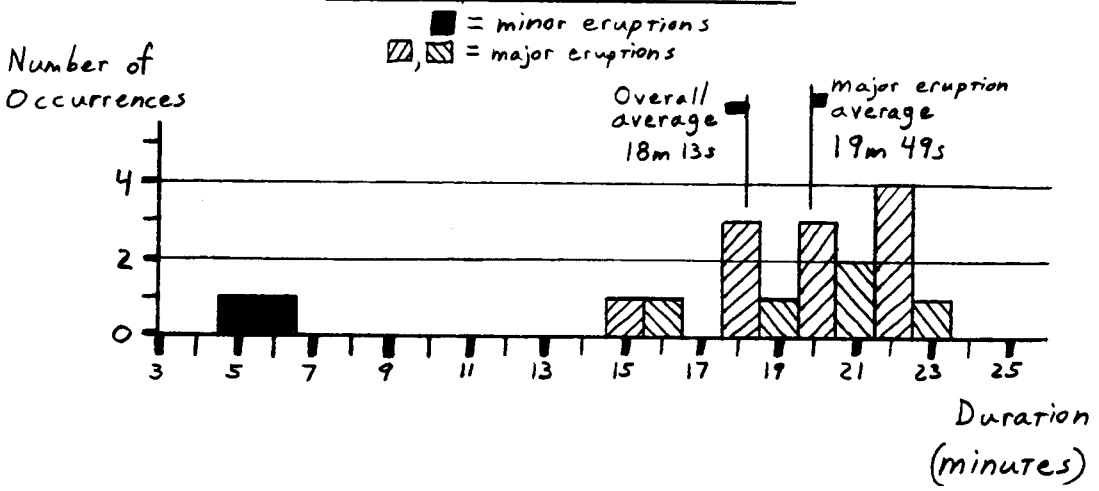
● = June 21 - September 12, 1987
(Weekly Average)



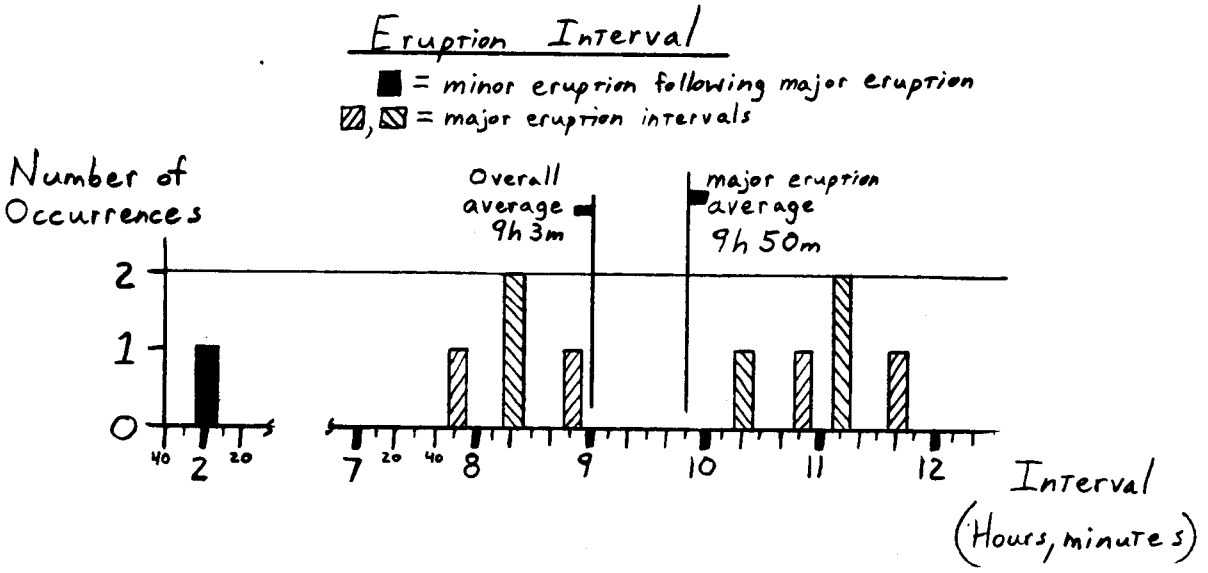
Artemisia Geyser

May - October, 1988

Eruption Duration



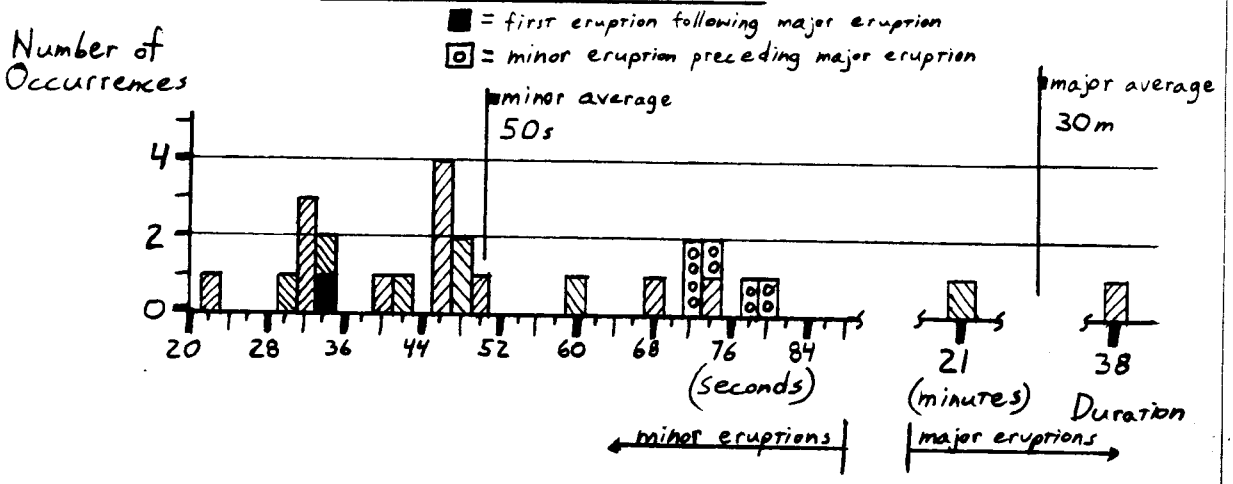
Eruption Interval



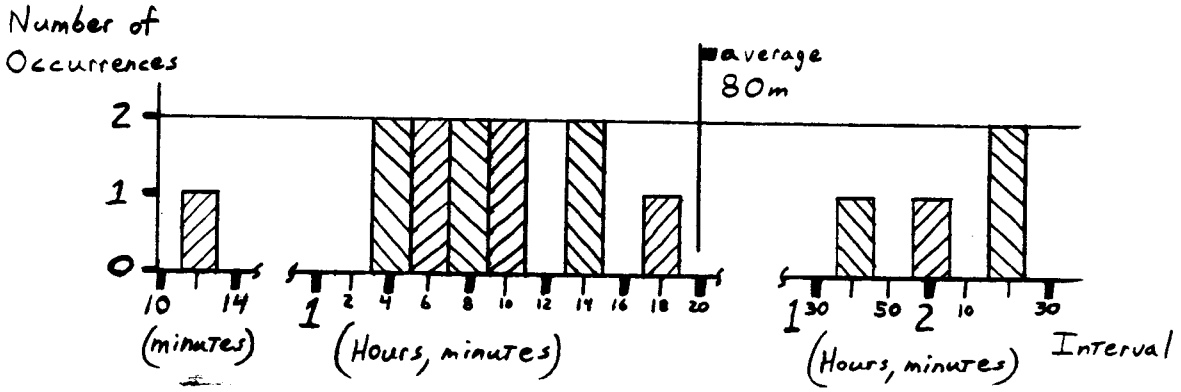
Atomizer Geyser

May - October, 1988

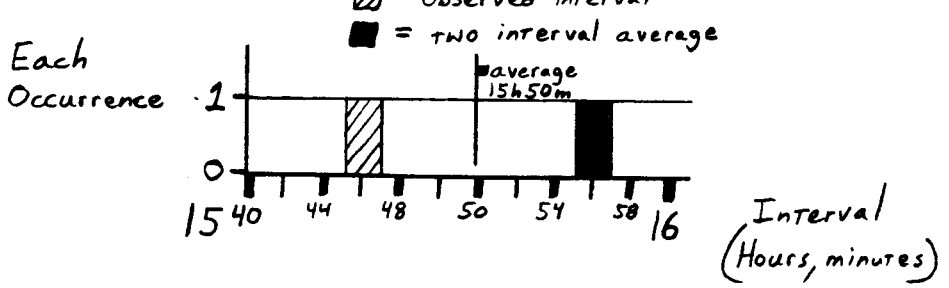
Eruption Duration



Eruption Interval (within eruption series)



Interval Between Major Eruptions



Atomizer Geyser

1988

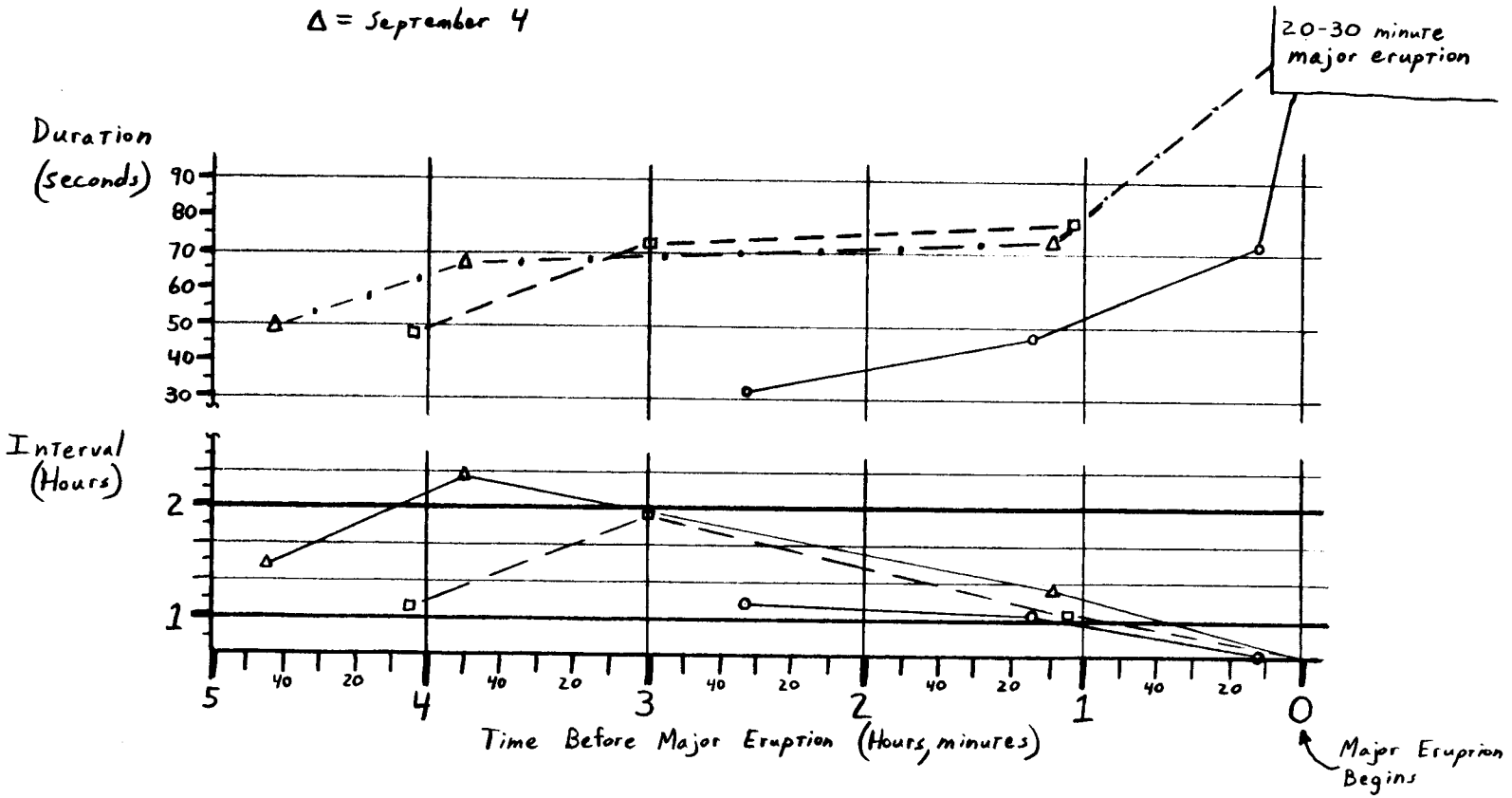
Activity Leading to Major Eruption

All data possibly collected by Lynn Stephens

○ = August 26

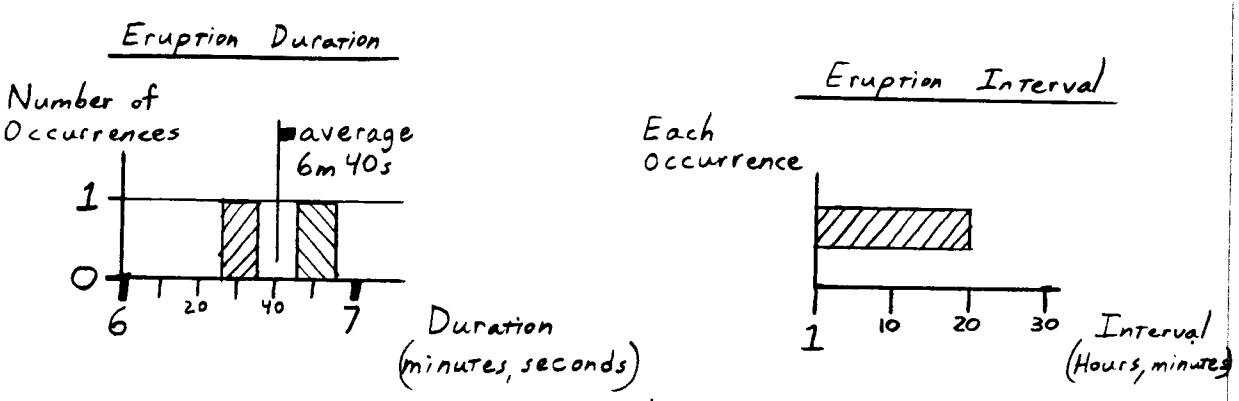
□ = September 1

△ = September 4

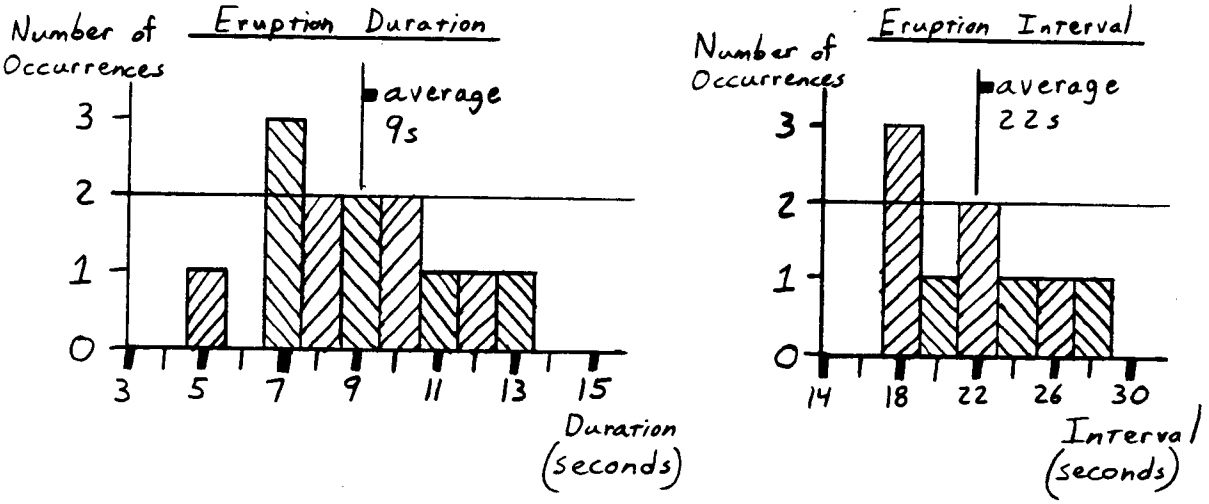


A-2 Geyser

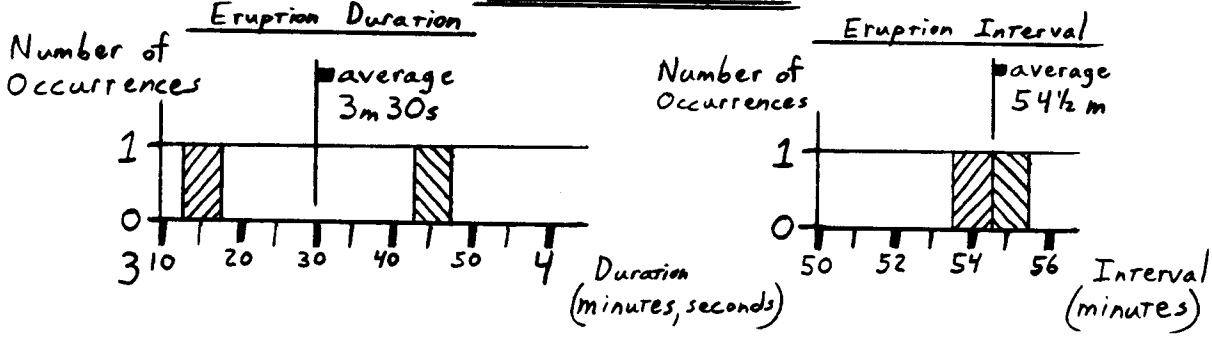
All data collected on July 7, 1988



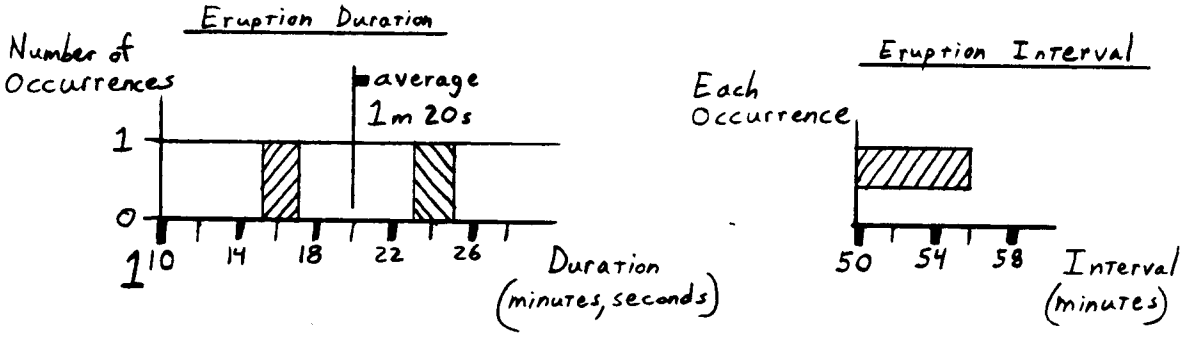
Boiling Spring



Crack Geyser



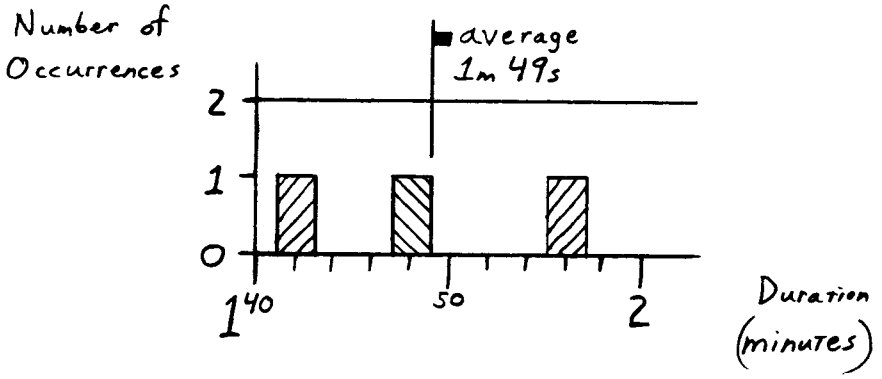
Gemini Geyser



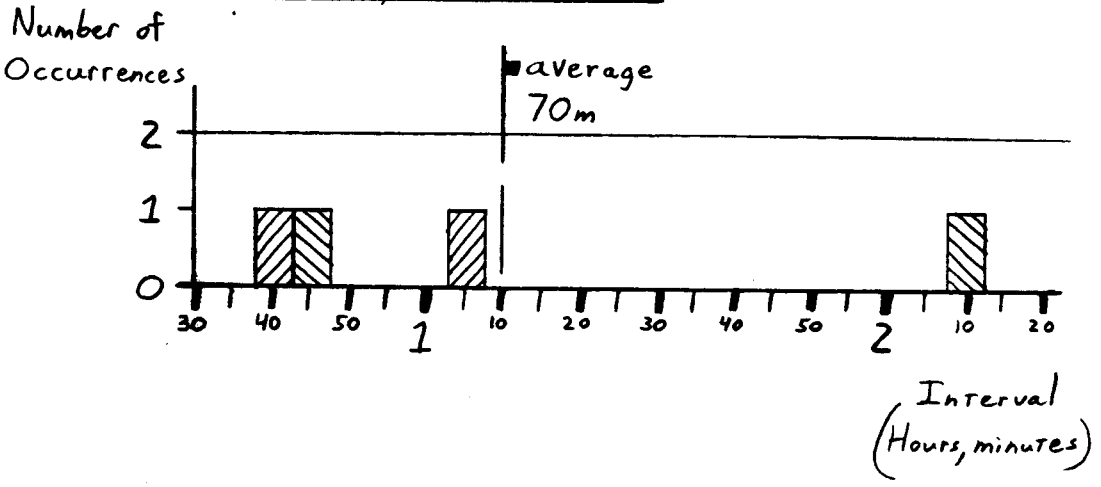
White Dome Geyser

July 7, 1988

Eruption Duration



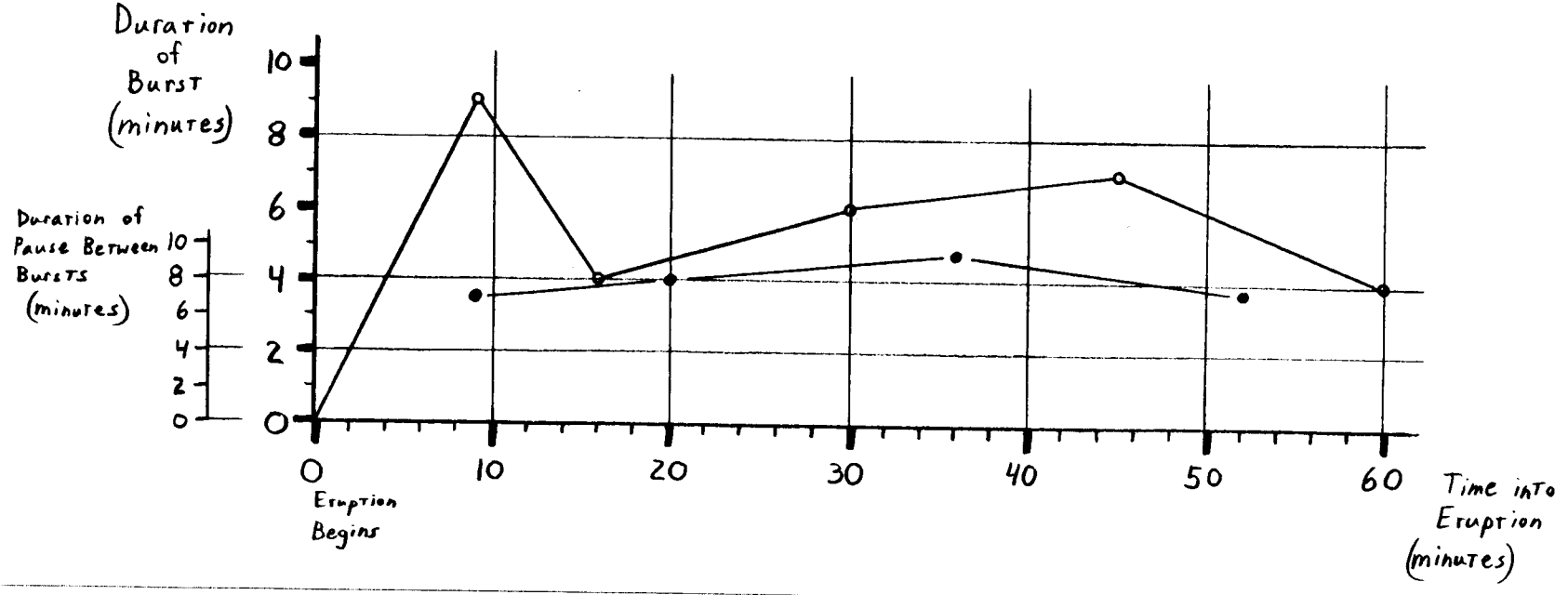
Eruption Interval



Great Fountain Geyser

July 7, 1988

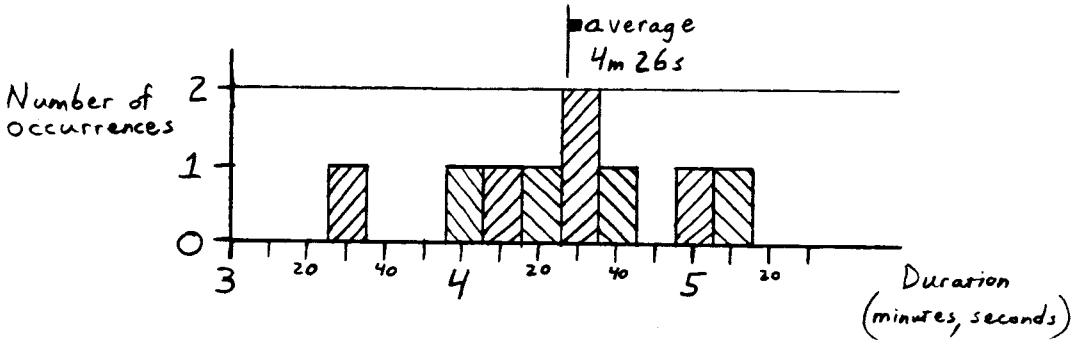
Individual Eruption Durations vs. Time into Main Eruption



"North" Angle Geyser

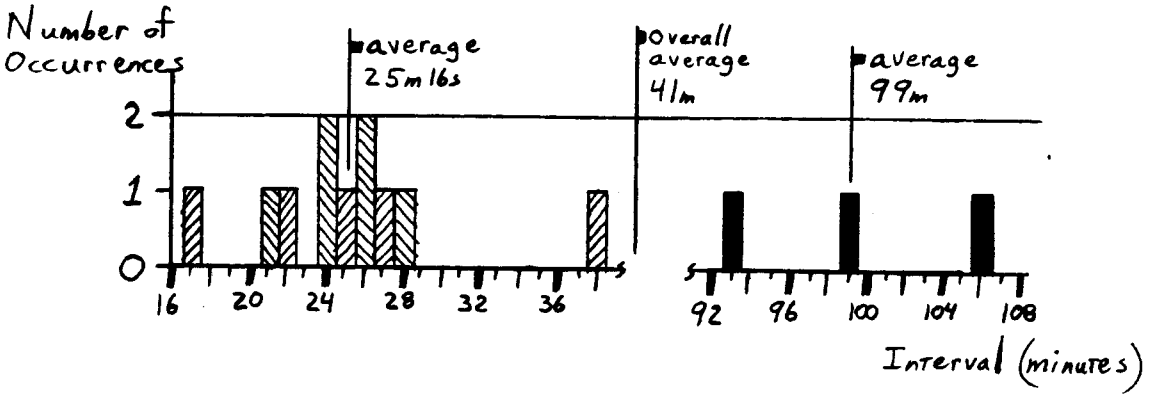
June 17, 1988

Eruption Duration



Eruption Interval

■ = includes eruption of Northwest Angle Geyser

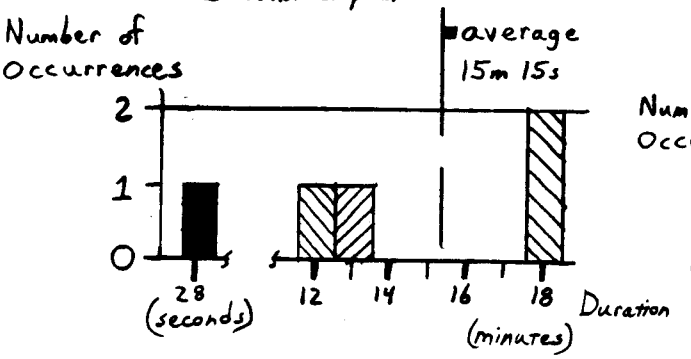


"South" Angle Geyser

June 17, 1988

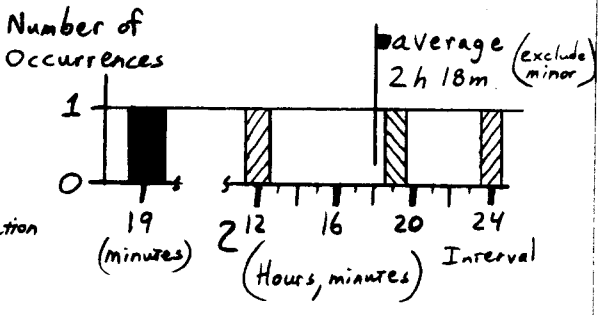
Eruption Duration

■ = minor eruption



Eruption Interval

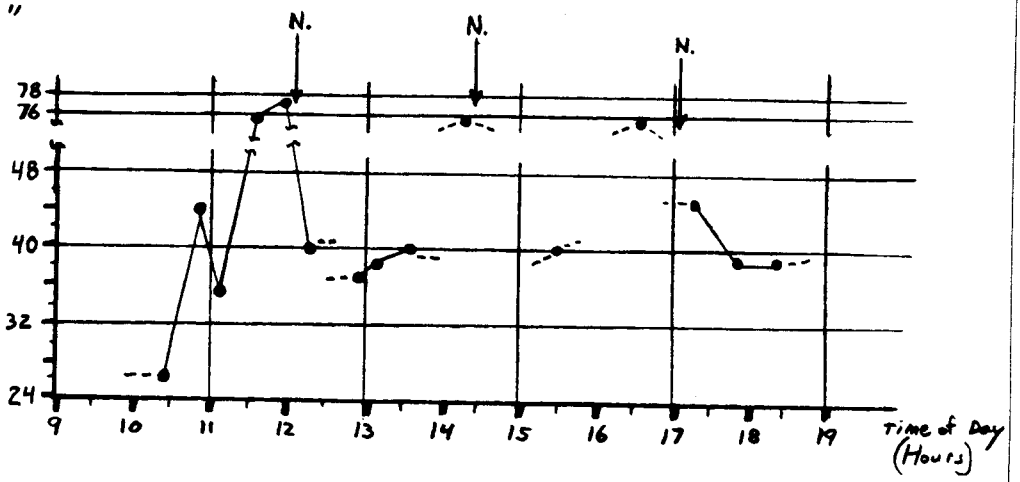
■ = minor eruption follows major eruption



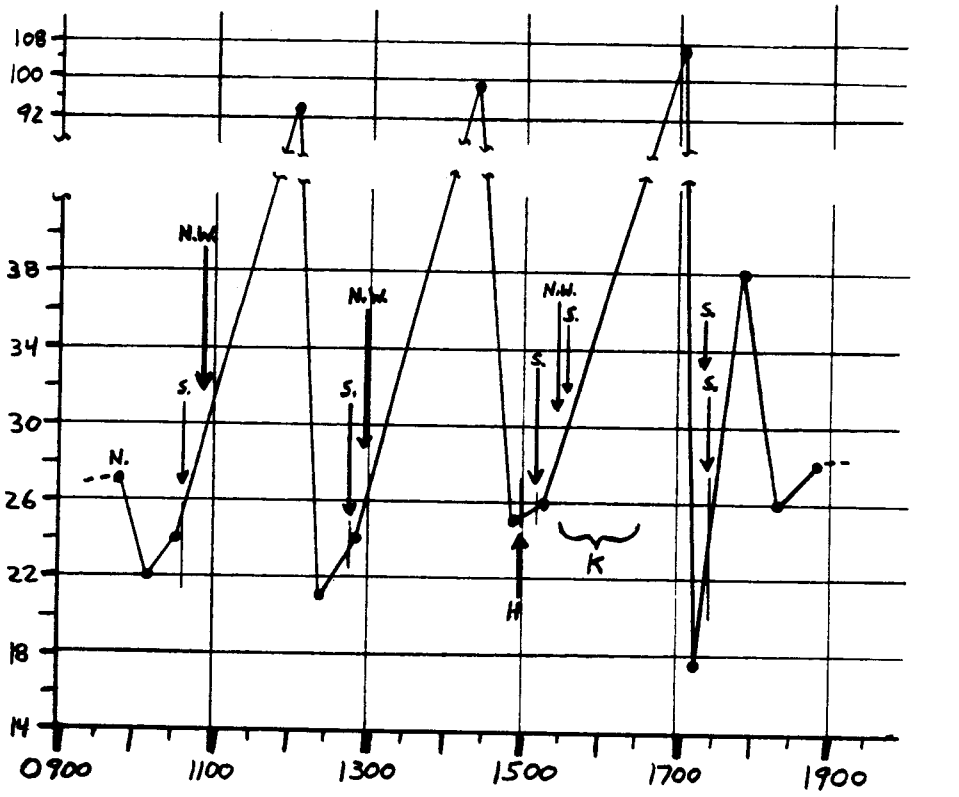
Angle Group, Area Activity

June 17, 1988

"Little Crack" Duration (seconds)



"North" Angle Interval (minutes)

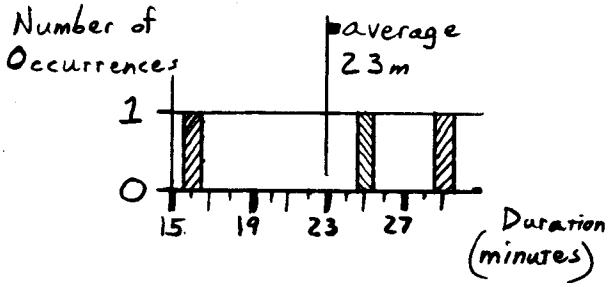


H = Honeycomb
K = kaleidoscope
N. = North Angle
N.W. = North West Angle
S. = South Angle

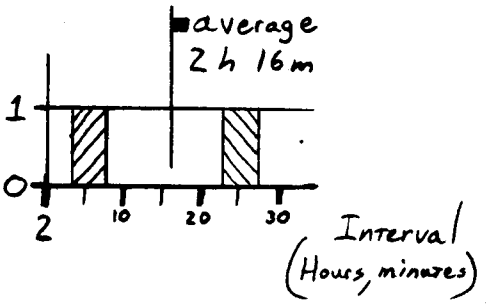
"North-West" Angle Geyser

June 17, 1988

Eruption Duration



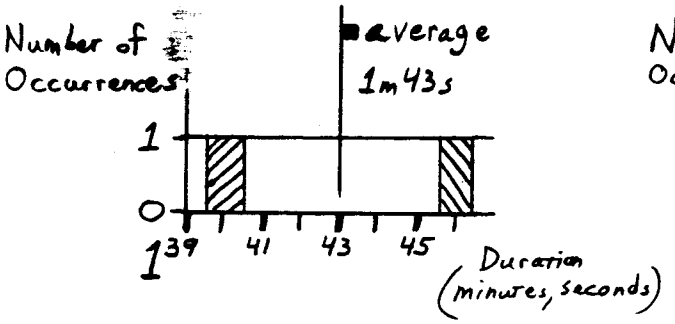
Eruption Interval



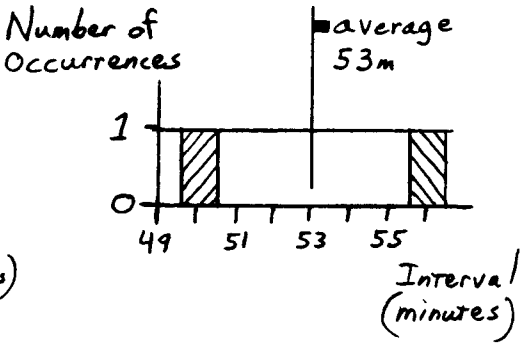
"Little" Angle Geyser

June 17, 1988

Eruption Duration



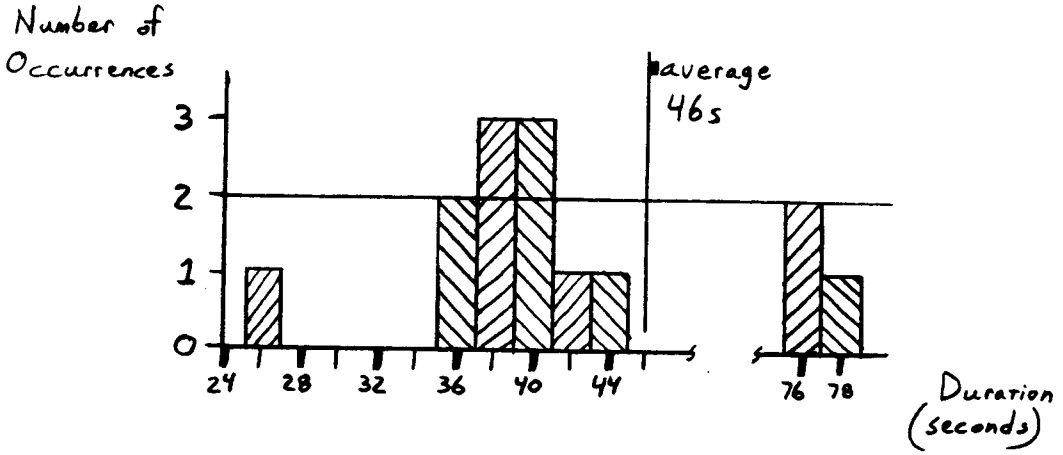
Eruption Interval



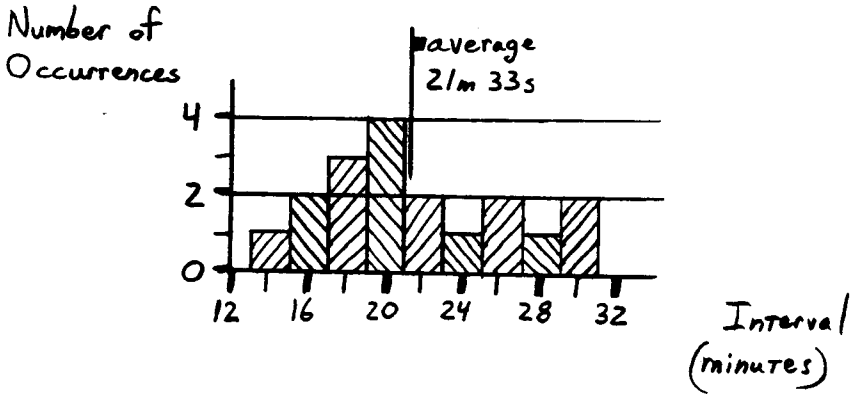
"Little Crack" Geyser

June 17, 1988

Eruption Duration



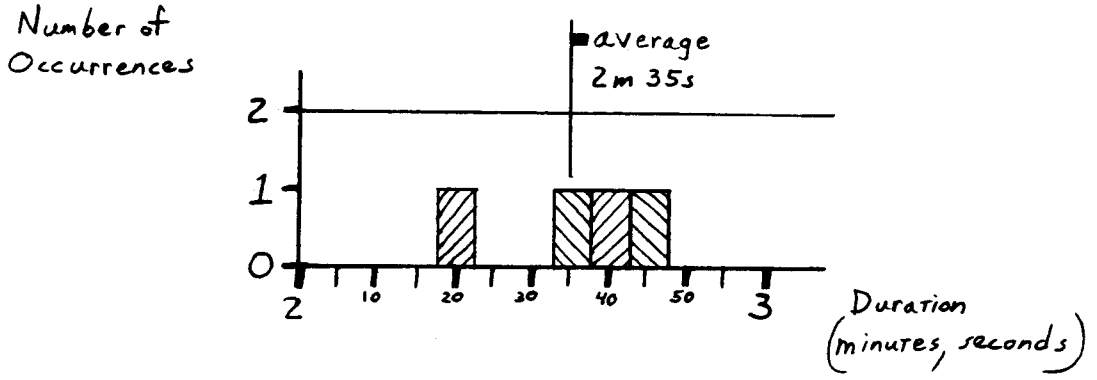
Eruption Interval



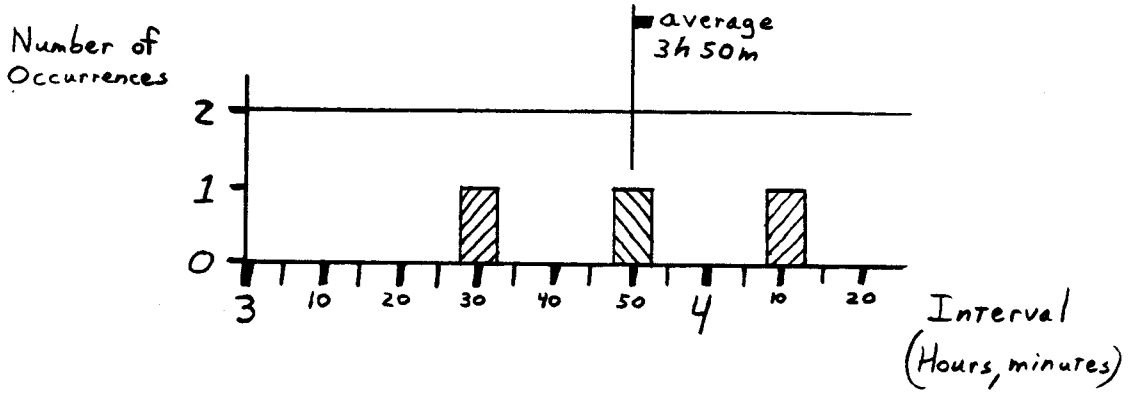
Blowout Geyser

June 17, 1988

Eruption Duration



Eruption Interval

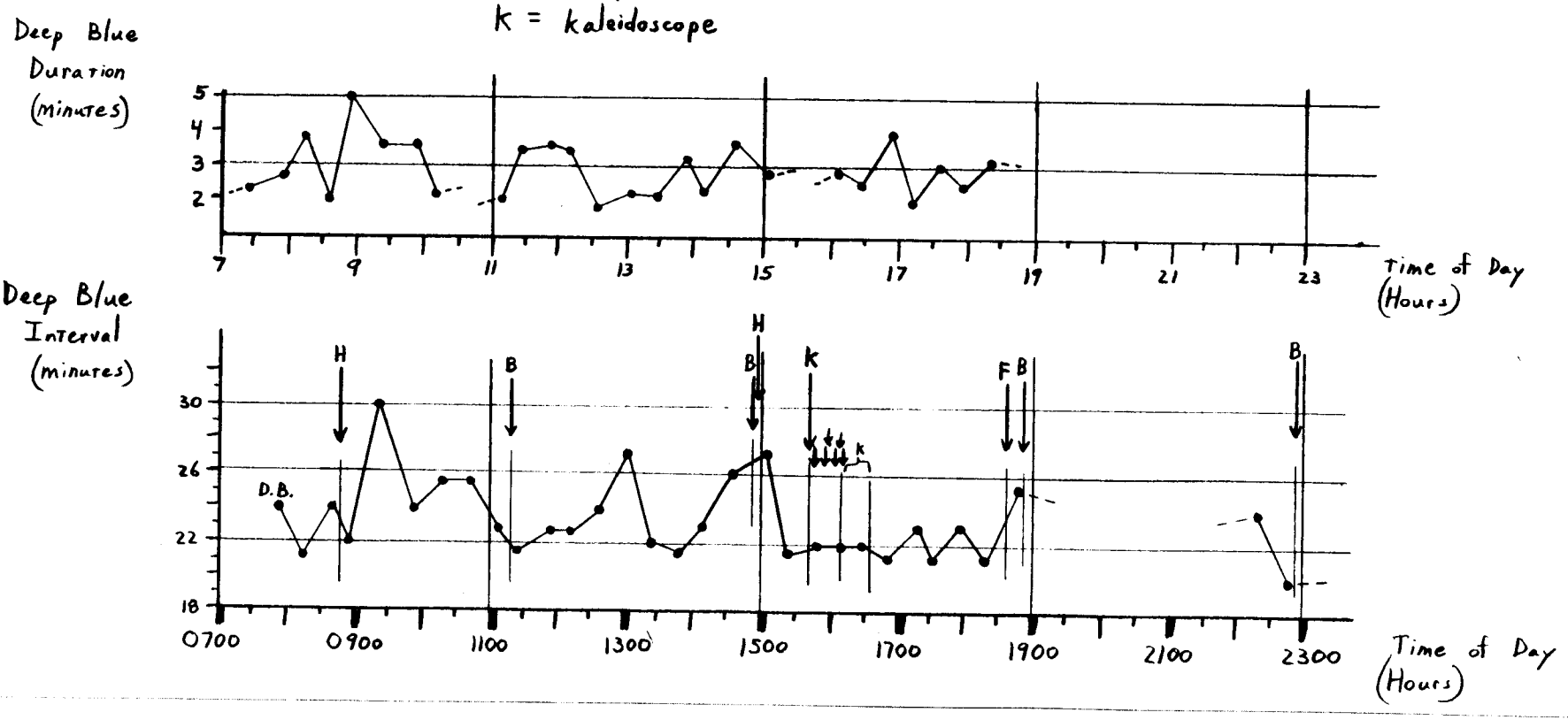


Deep Blue Geyser Area Activity

June 17, 1988

B = Blowout
D.B. = Deep Blue
F = Fountain
H = Honeycomb
k = kaleidoscope

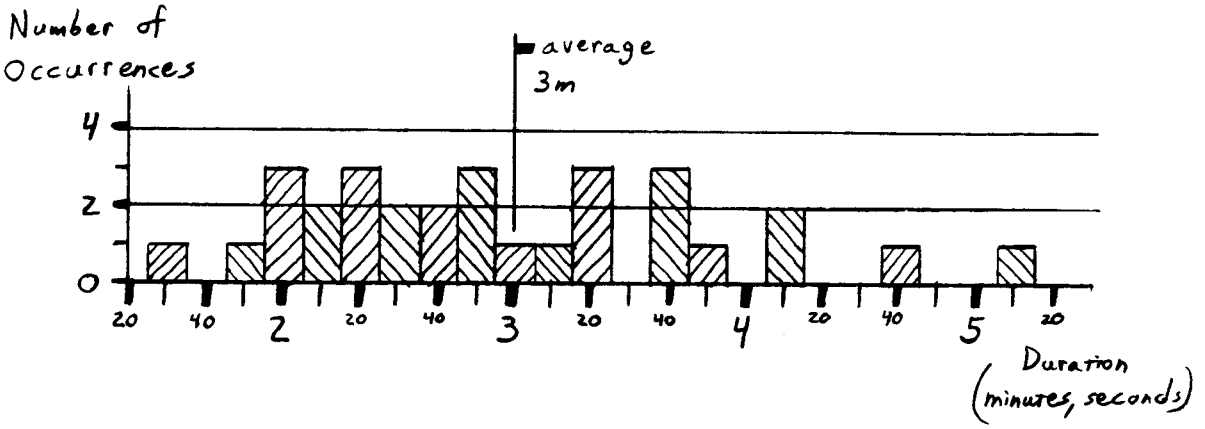
Deep Blue Satellite Vent Active the entire day. (constant eruption)



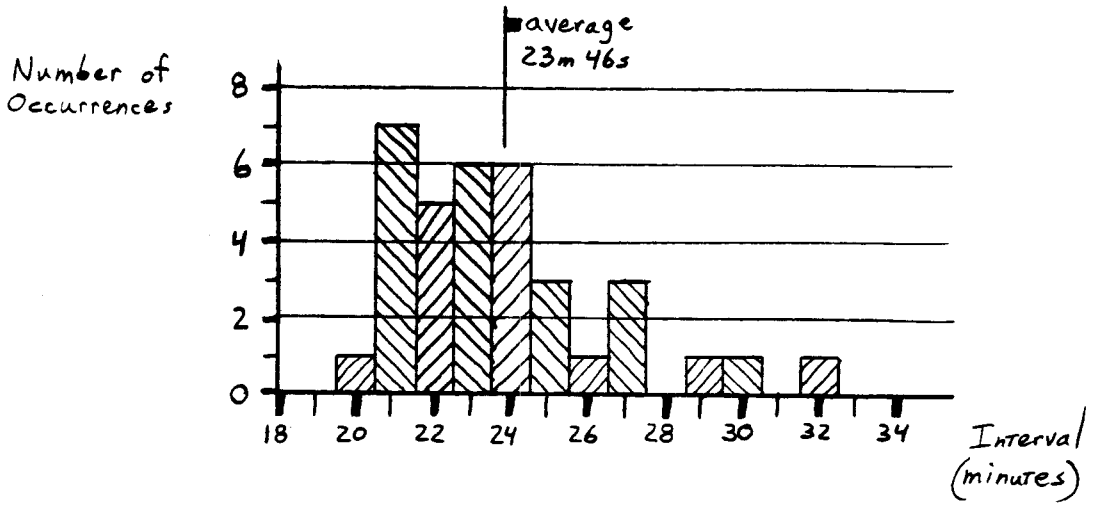
Deep Blue Geyser

June 17 + October 28, 1988

Eruption Duration



Eruption Interval

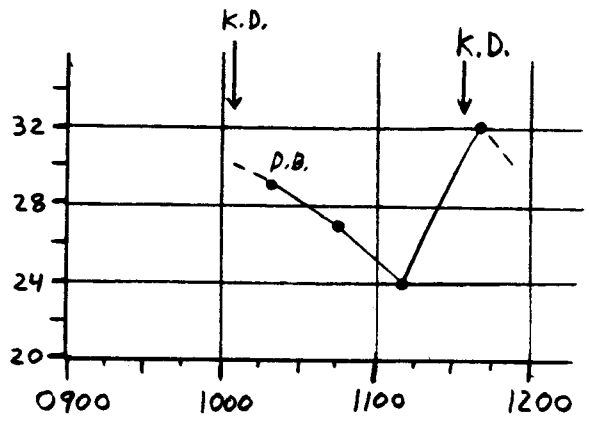


Deep Blue Geyser and Kaleidoscopes Drain Geyser

October 28, 1988

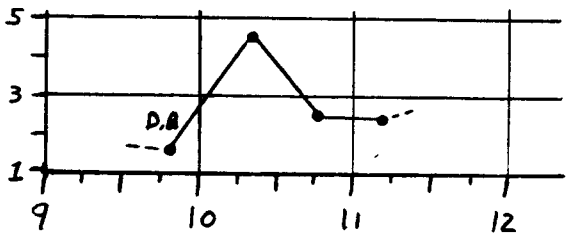
D.B. = Deep Blue
K.D. = kaleidoscopes Drain

Deep Blue Interval (minutes)



Time of Day (Hours)

Deep Blue Duration (minutes)

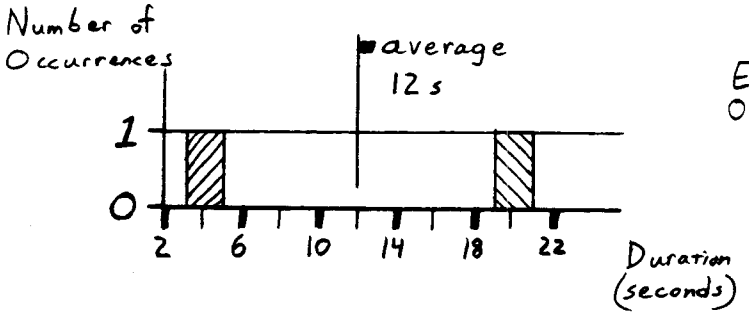


Time of Day (Hours)

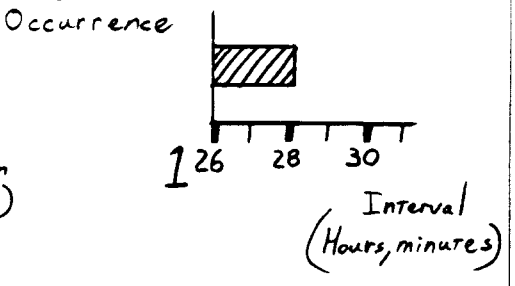
Kaleidoscope's Drain Geyser

October 28, 1988

Eruption Duration



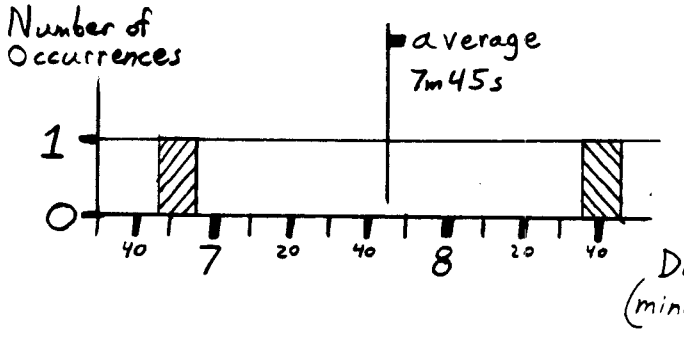
Eruption Interval



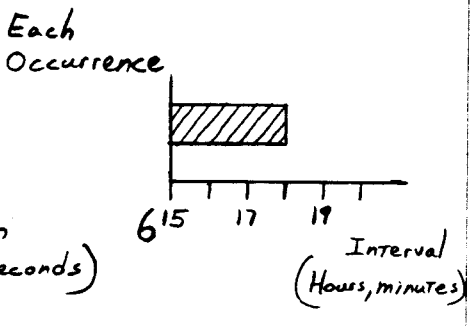
Honeycomb Geyser

June 17, 1988

Eruption Duration



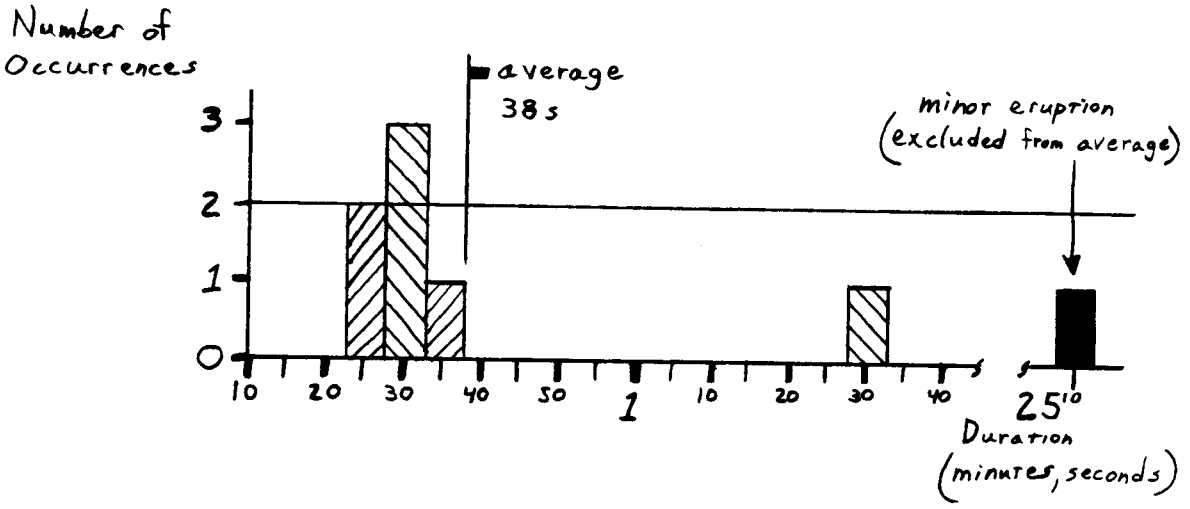
Eruption Interval



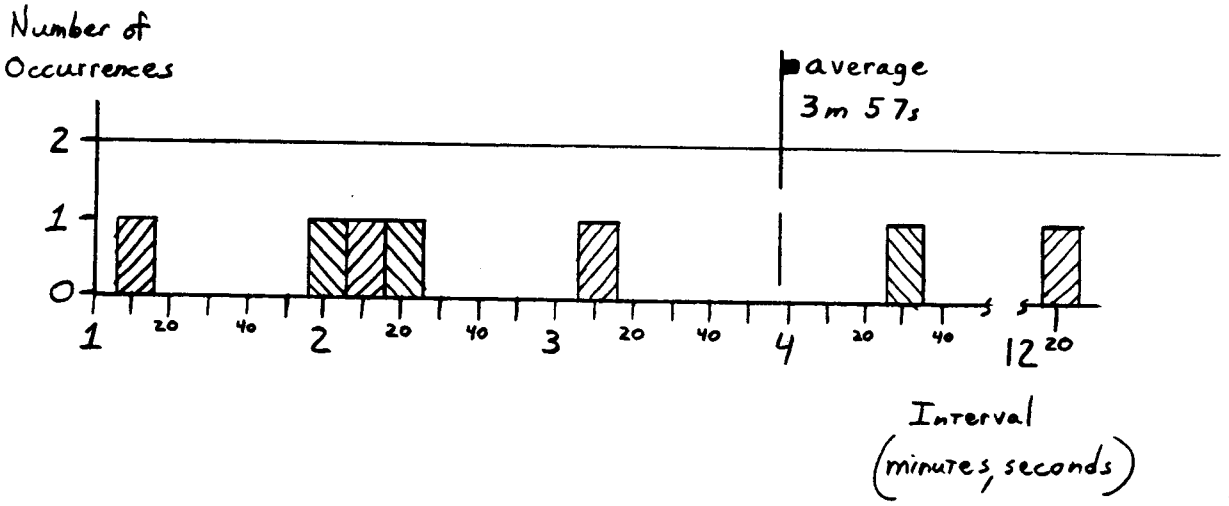
Kaleidoscope Geyser

June 17, 1988

Eruption Duration



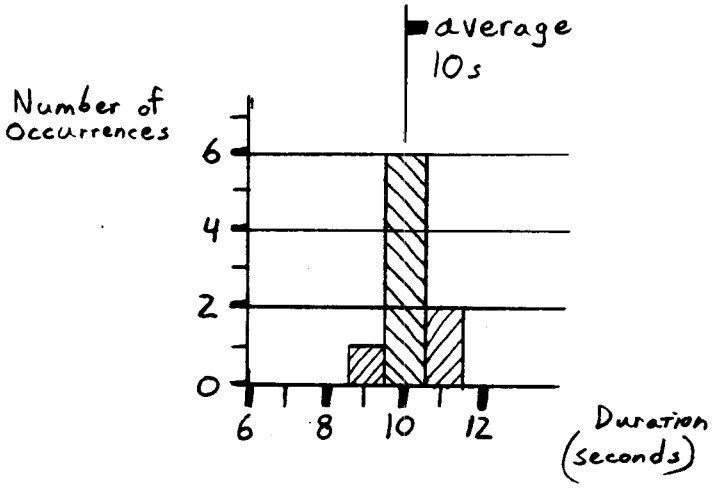
Eruption Interval



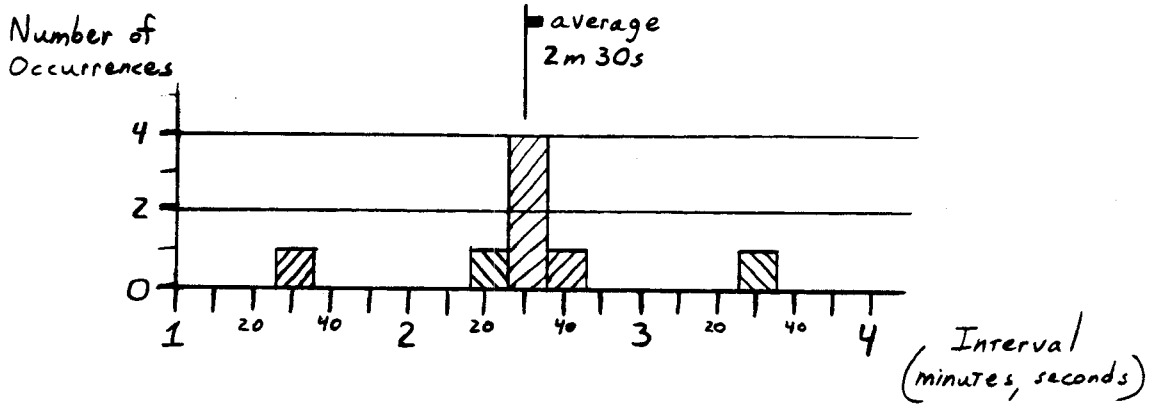
Sprinkler Geyser

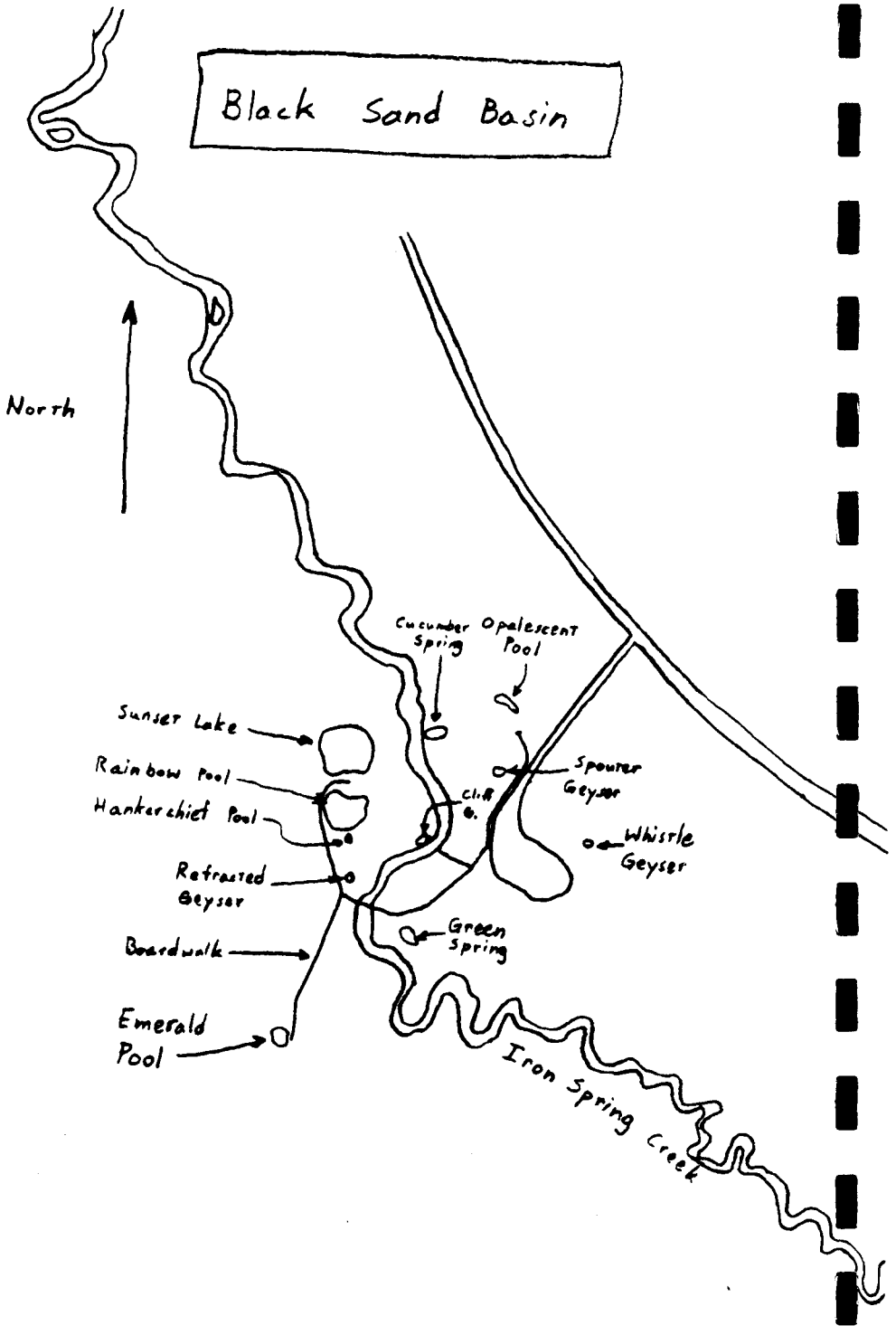
June 17, 1988

Eruption Duration

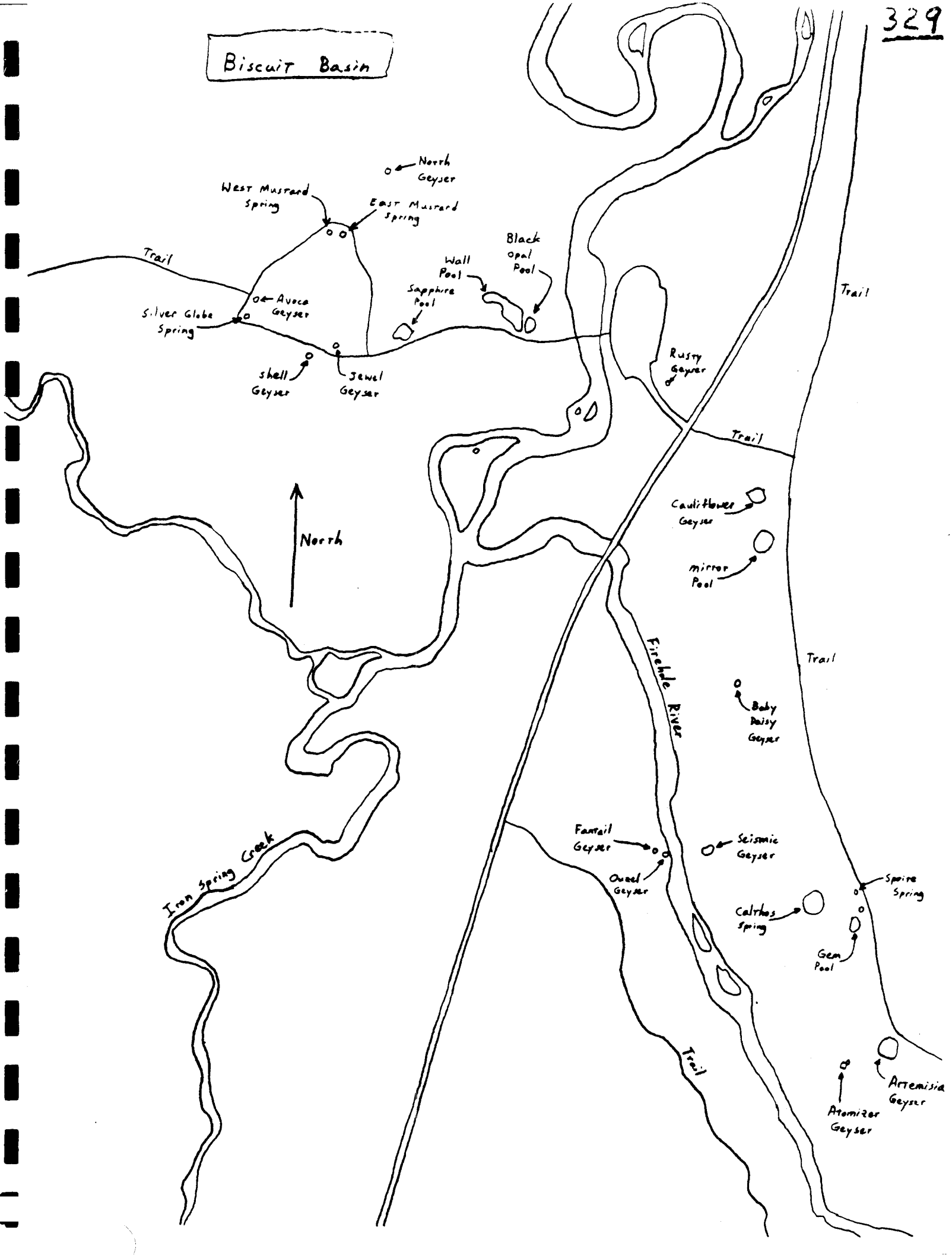


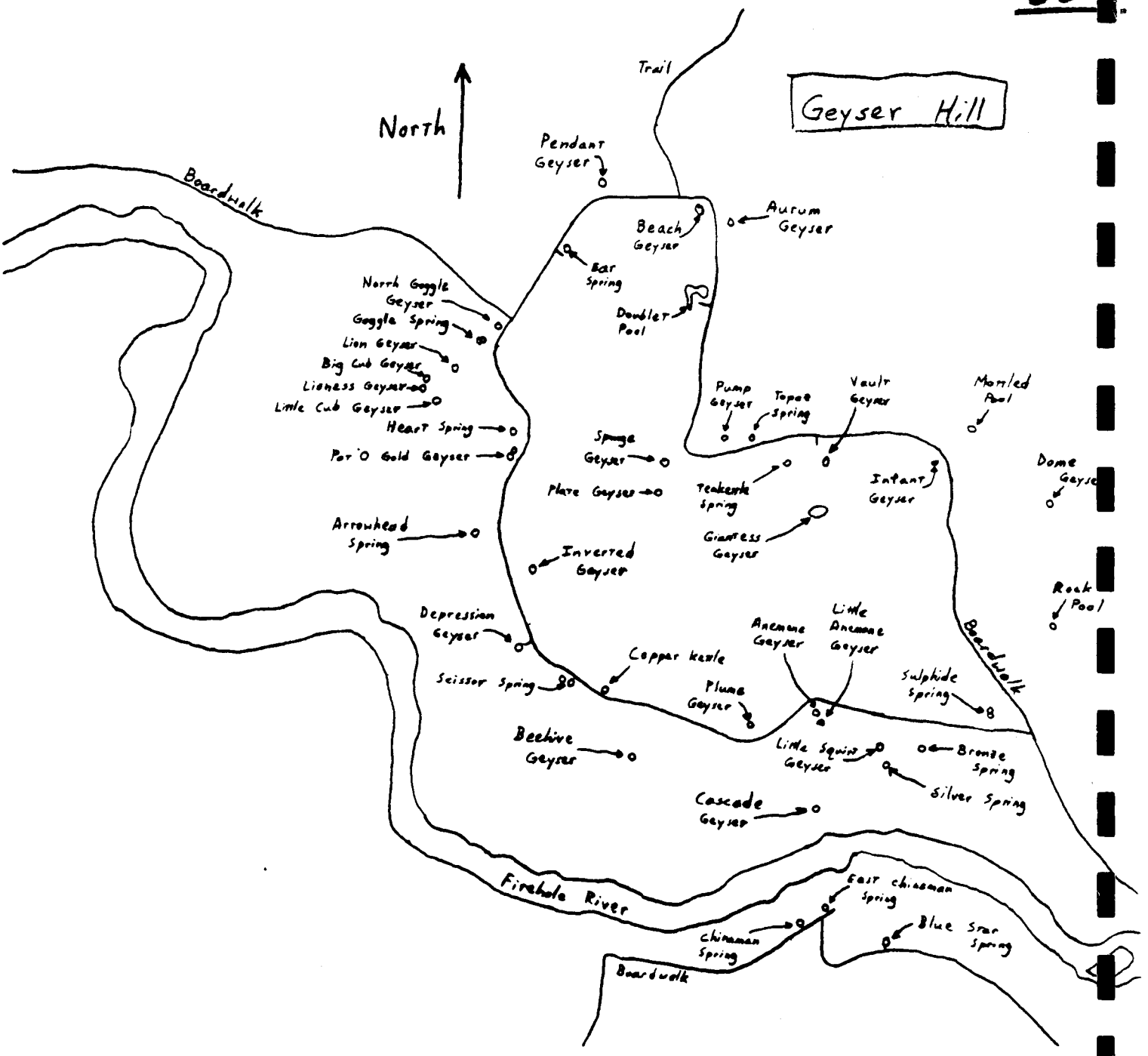
Eruption Interval




Black Sand Basin
North
Cucumber Spring
Opalescent Pool
Sunset Lake
Rainbow Pool
Handkerchief Pool
Spouter Geyser
Cliff
Whistle Geyser
Refrosted Geyser
Green Spring
Boardwalk
Emerald Pool
Iron Spring Creek

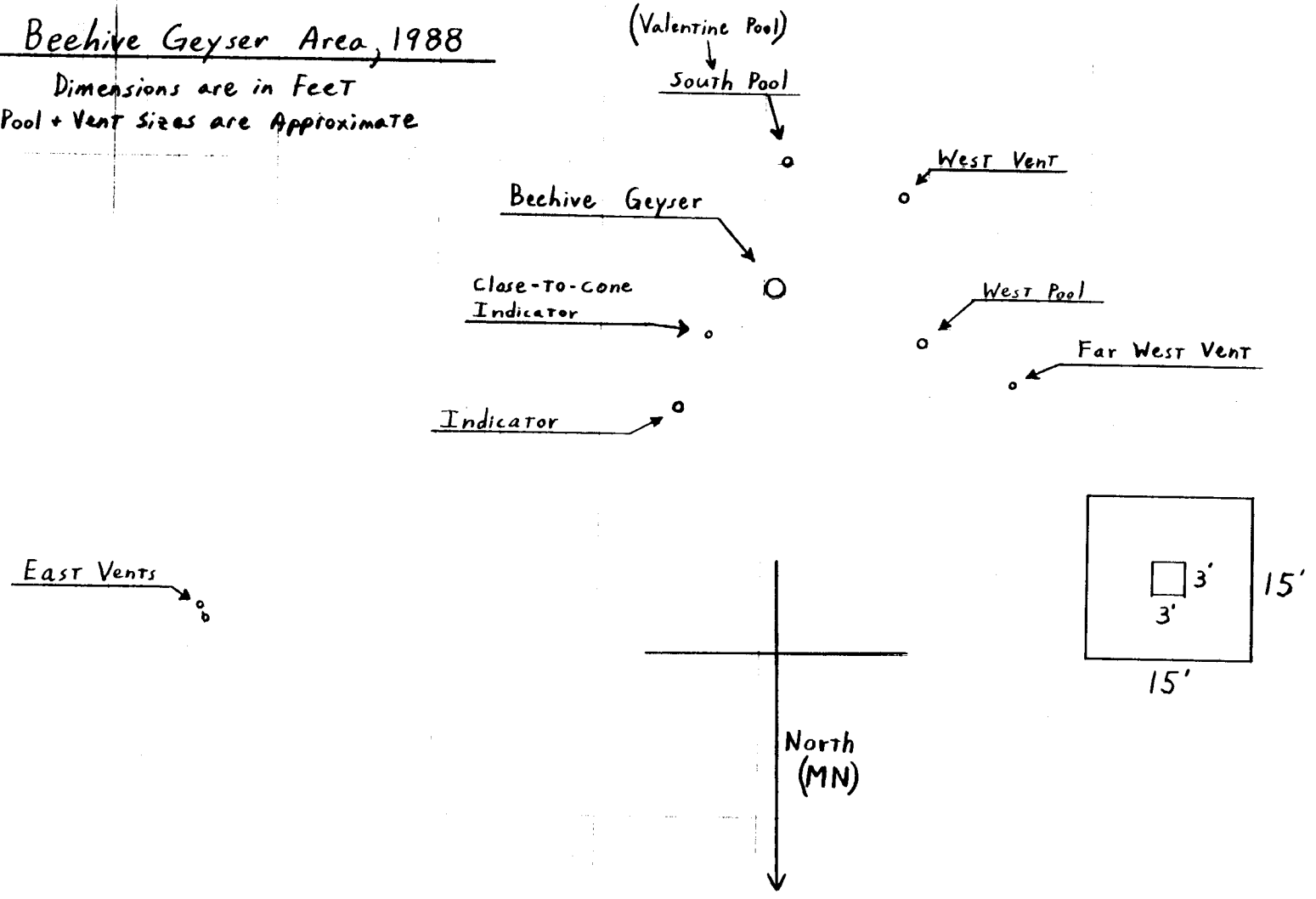
Biscuit Basin

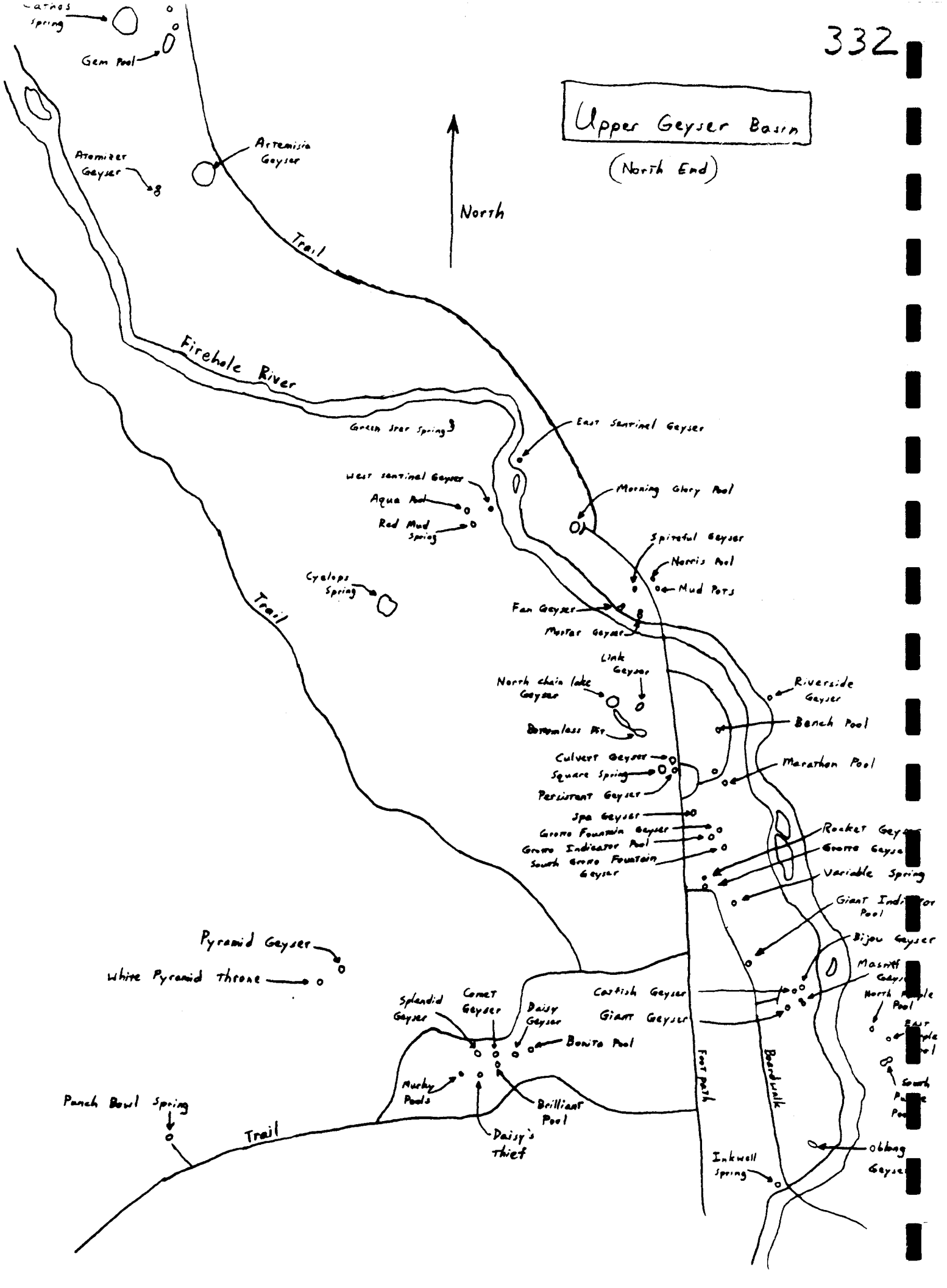


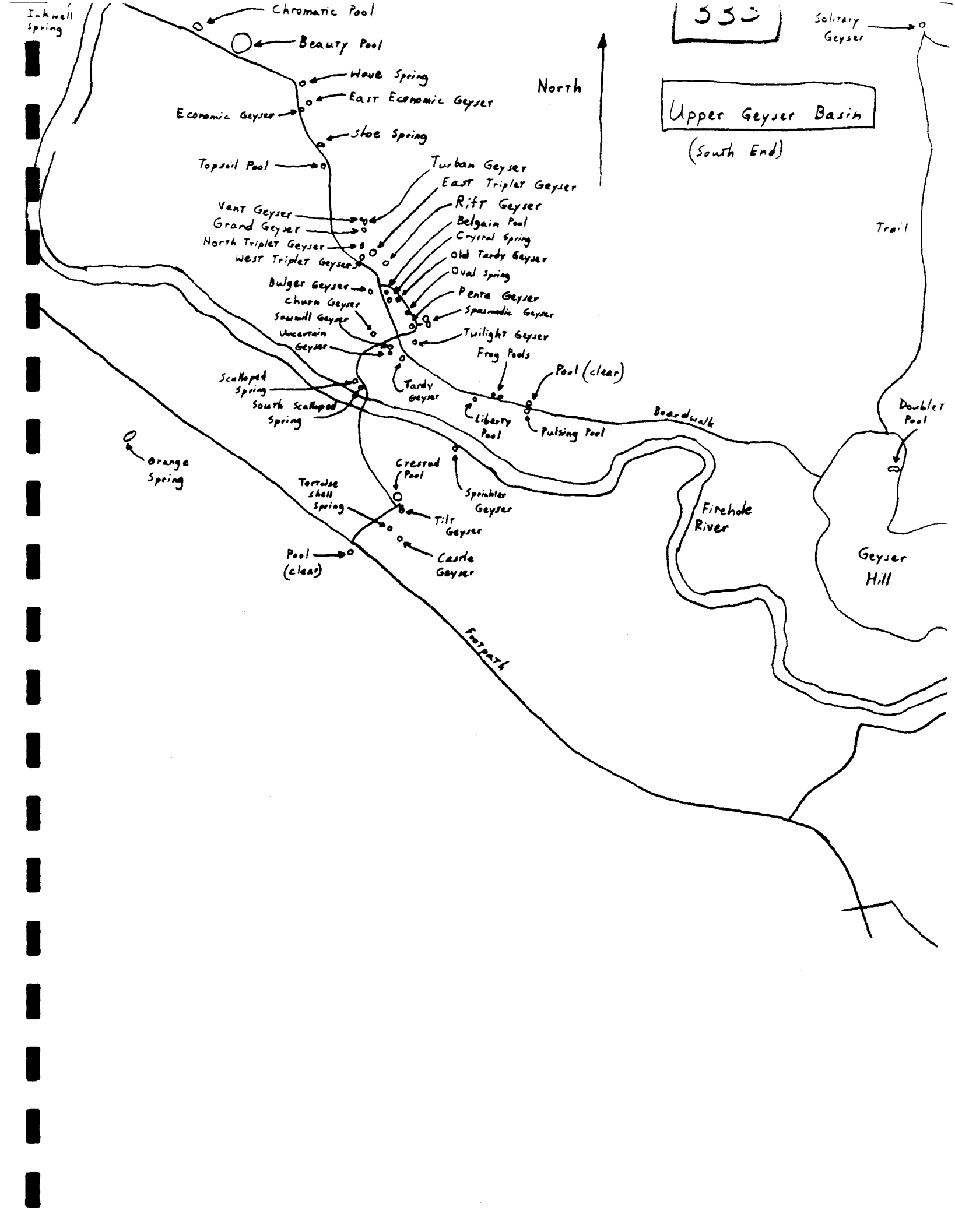

Geyser Hill
North
Trail
Pendant Geyser
Boardwalk
Beach Geyser
Aurum Geyser
Bar Spring
Doublet Pool
North Goggle Geyser
Goggle Spring
Lion Geyser
Big Cub Geyser
Lioness Geyser
Little Cub Geyser
Heart Spring
Par 'O Gold Geyser
Pump Geyser
Topaz Spring
Vault Geyser
Mottled Pool
Sponge Geyser
Plate Geyser
Teakettle Spring
Infant Geyser
Dome Geyser
Arrowhead Spring
Grantess Geyser
Inverted Geyser
Rock Pool
Depression Geyser
Scissor Spring
Copper Kettle
Anemone Geyser
Little Anemone Geyser
Boardwalk
Plume Geyser
Sulphide Spring
Beehive Geyser
Little Squirt Geyser
Bronze Spring
Silver Spring
Cascade Geyser
Firehole River
East Chinaman Spring
Chinaman Spring
Blue Star Spring
Boardwalk

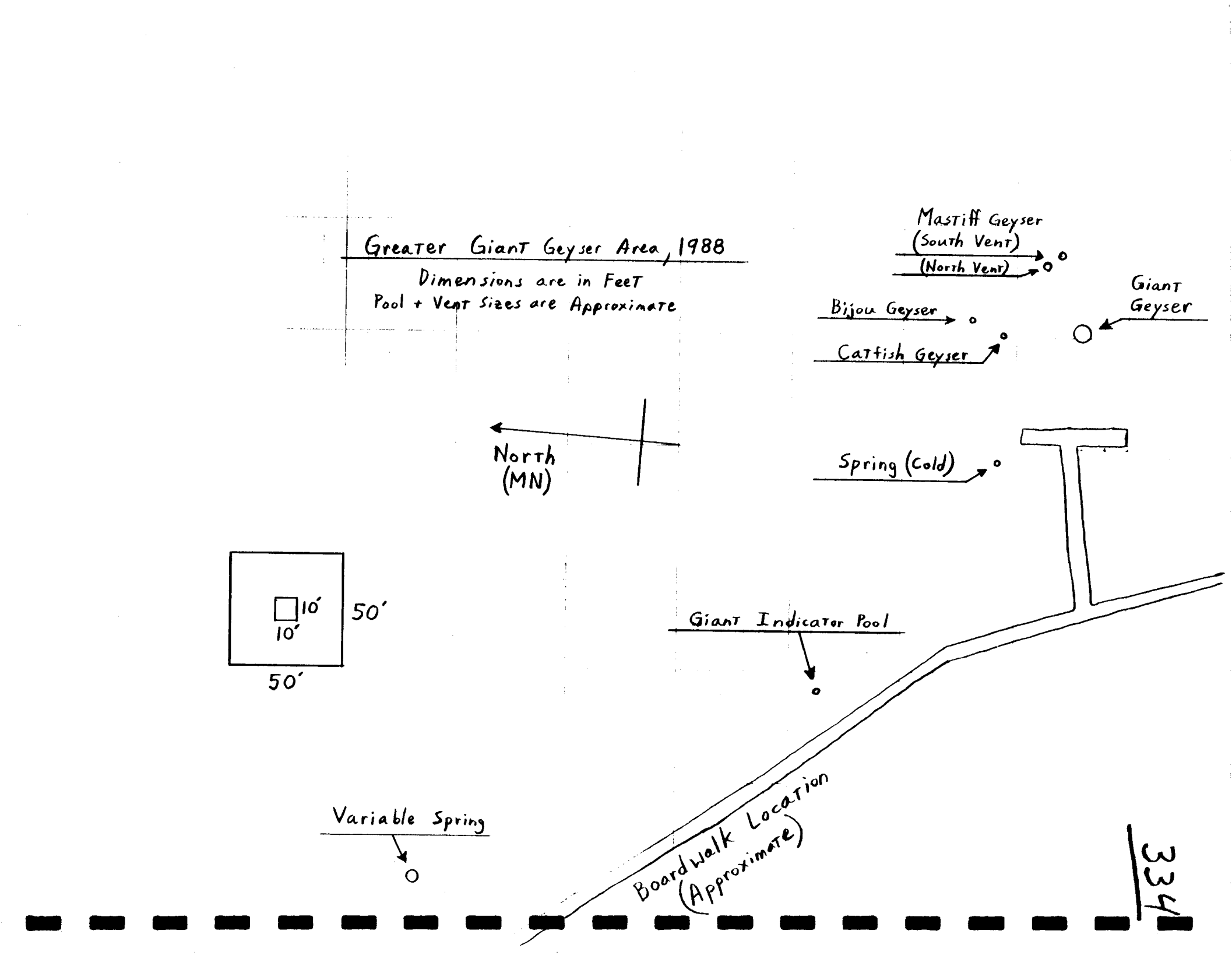
Beehive Geyser Area, 1988

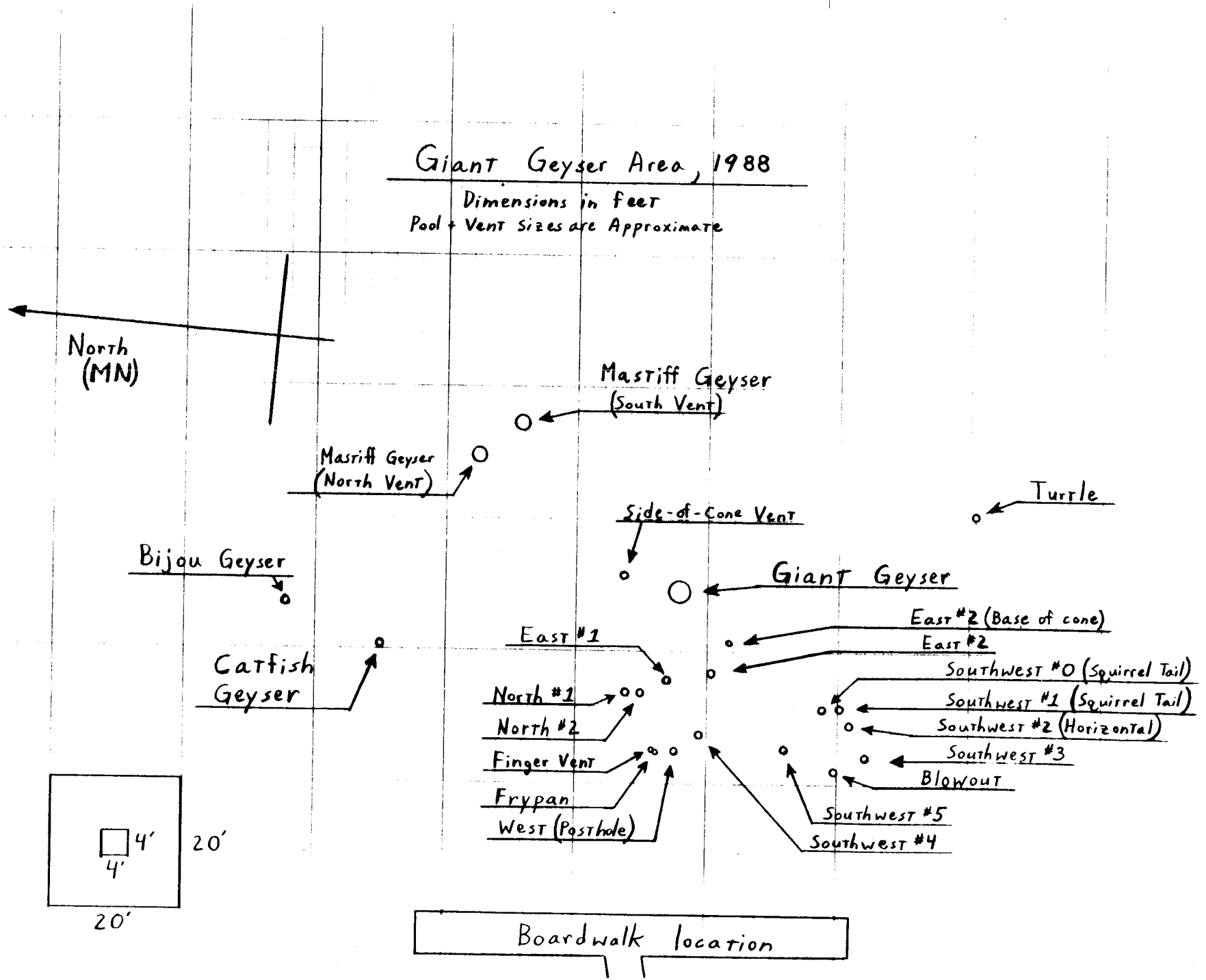
Dimensions are in Feet
Pool + Vent Sizes are Approximate

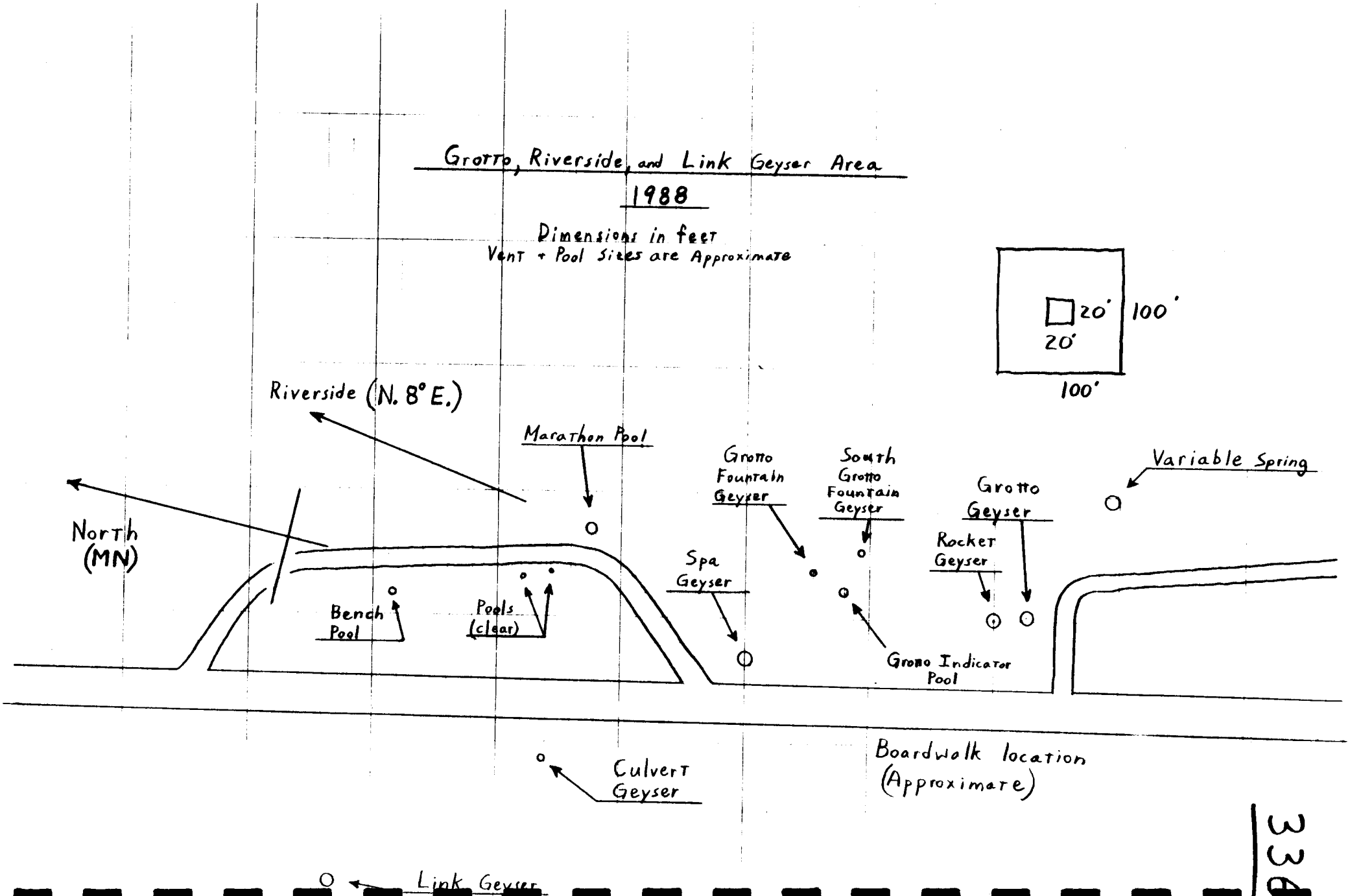


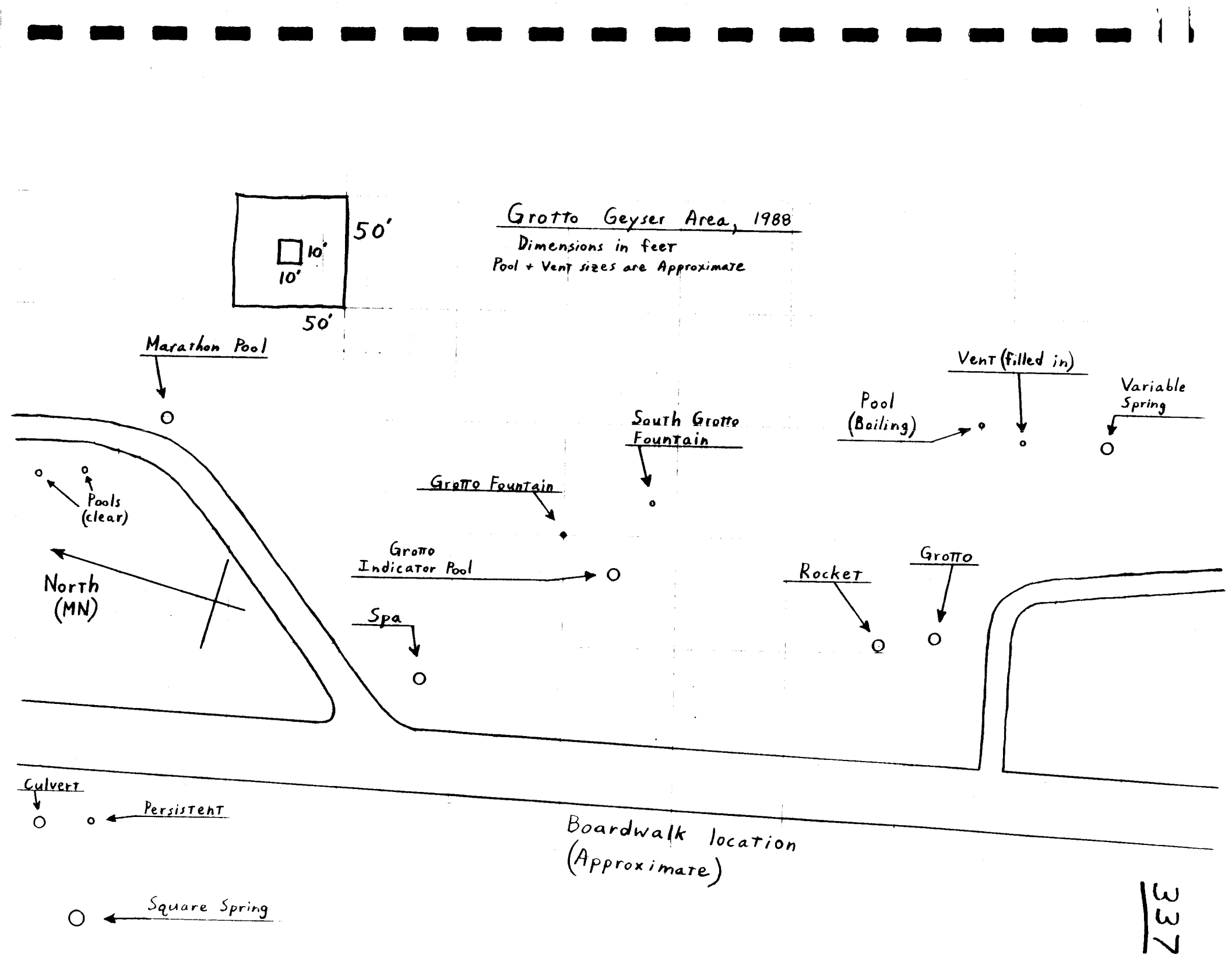

Upper Geyser Basin
(North End)
North
Gem Pool
Artemisia Geyser
Atomizer Geyser
Trail
Firehole River
Green Spar Spring
East Sentinel Geyser
West sentinel Geyser
Aqua Pool
Red Mud Spring
Morning Glory Pool
Spiteful Geyser
Norris Pool
Mud Pots
Cyclops Spring
Trail
Fan Geyser
Mortar Geyser
Link Geyser
North chain lake Geyser
Riverside Geyser
Bench Pool
Marathon Pool
Culvert Geyser
Square Spring
Persistent Geyser
Spa Geyser
Grotto Fountain Geyser
Grotto Indicator Pool
South Grotto Fountain Geyser
Rocket Geyser
Grotto Geyser
Variable Spring
Giant Indicator Pool
Bijou Geyser
Pyramid Geyser
White Pyramid Throne
Splendid Geyser
Comet Geyser
Daisy Geyser
Bonita Pool
Catfish Geyser
Giant Geyser
Footpath
Boardwalk
Murky Pools
Brilliant Pool
Daisy's Thief
Punch Bowl Spring
Trail
Inkwell Spring
Oblong Geyser

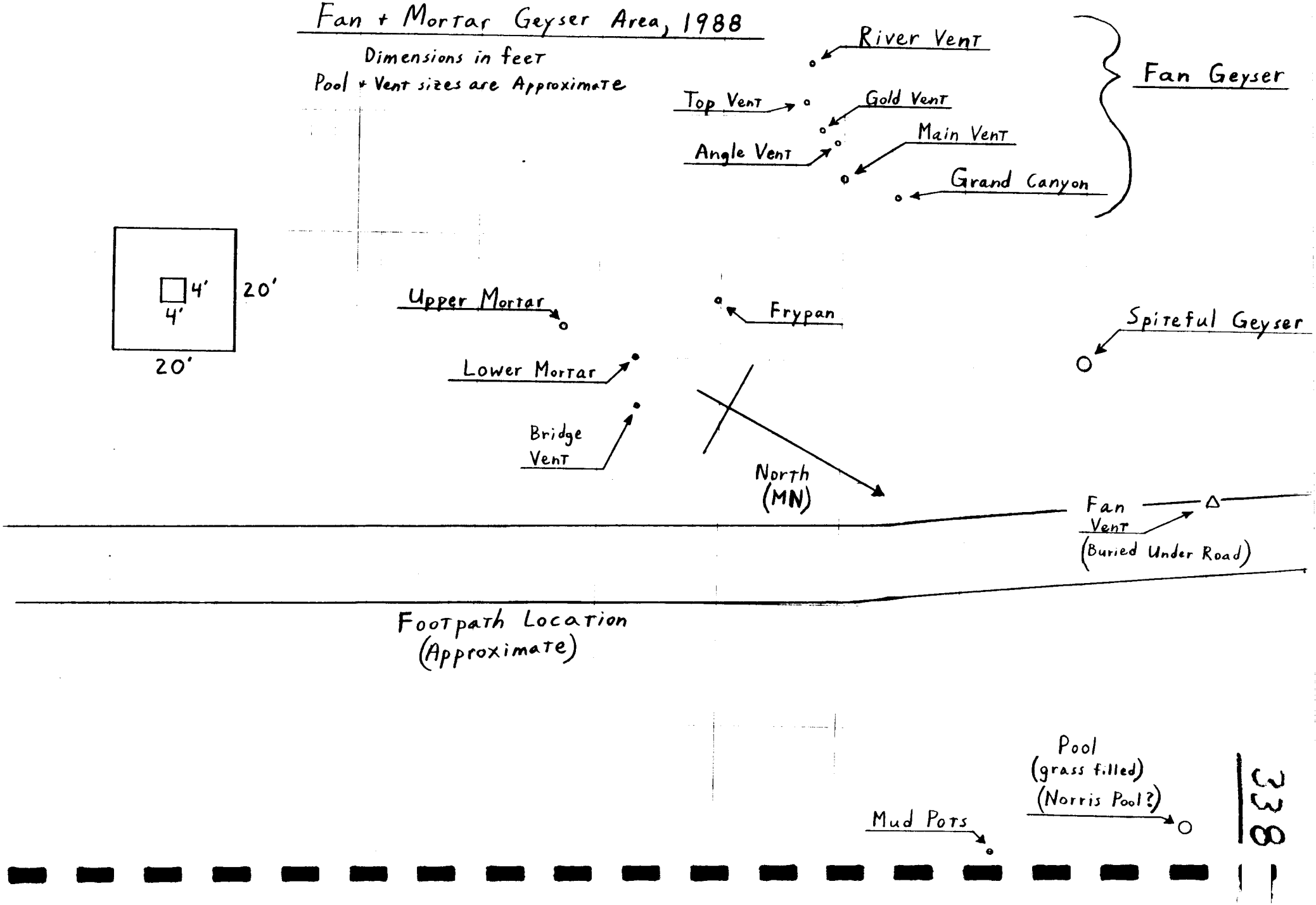

Upper Geyser Basin
(South End)
North
Inkwell Spring
Chromatic Pool
Beauty Pool
Wave Spring
East Economic Geyser
Economic Geyser
Shoe Spring
Topsoil Pool
Turban Geyser
East Triplet Geyser
Rift Geyser
Vent Geyser
Grand Geyser
Belgain Pool
Crystal Spring
North Triplet Geyser
Old Tardy Geyser
West Triplet Geyser
Oval Spring
Bulger Geyser
Penta Geyser
Churn Geyser
Spasmodic Geyser
Sawmill Geyser
Twilight Geyser
Uncertain Geyser
Frog Pools
Pool (clear)
Scalloped Spring
Tardy Geyser
South Scalloped Spring
Liberty Pool
Pulsing Pool
Boardwalk
Doublet Pool
Orange Spring
Crested Pool
Sprinkler Geyser
Tortoise Shell Spring
Tilt Geyser
Firehole River
Pool (clear)
Castle Geyser
Geyser Hill
Footpath
Solitary Geyser
Trail


Greater Giant Geyser Area, 1988
Dimensions are in Feet
Pool + Vent Sizes are Approximate
Mastiff Geyser
(South Vent)
(North Vent)
Giant Geyser
Bijou Geyser
Catfish Geyser
North (MN)
Spring (Cold)
10'
10'
50'
50'
Giant Indicator Pool
Variable Spring
Boardwalk Location (Approximate)


Giant Geyser Area, 1988
Dimensions in feet
Pool + Vent sizes are Approximate
North (MN)
Mastiff Geyser (South Vent)
Mastiff Geyser (North Vent)
Turtle
Side-of-Cone Vent
Bijou Geyser
Giant Geyser
East #2 (Base of cone)
East #1
East #2
Catfish Geyser
Southwest #0 (Squirrel Tail)
Southwest #1 (Squirrel Tail)
North #1
Southwest #2 (Horizontal)
North #2
Southwest #3
Finger Vent
Blowout
Frypan
Southwest #5
West (Posthole)
Southwest #4
4'
4'
20'
20'
Boardwalk location


Grotto, Riverside, and Link Geyser Area
1988
Dimensions in feet
Vent + Pool Sizes are Approximate
20'
20'
100'
100'
Riverside (N. 8° E.)
Marathon Pool
Grotto Fountain Geyser
South Grotto Fountain Geyser
Grotto Geyser
Variable Spring
North (MN)
Rocket Geyser
Spa Geyser
Bench Pool
Pools (clear)
Grotto Indicator Pool
Boardwalk location (Approximate)
Culvert Geyser
Link Geyser

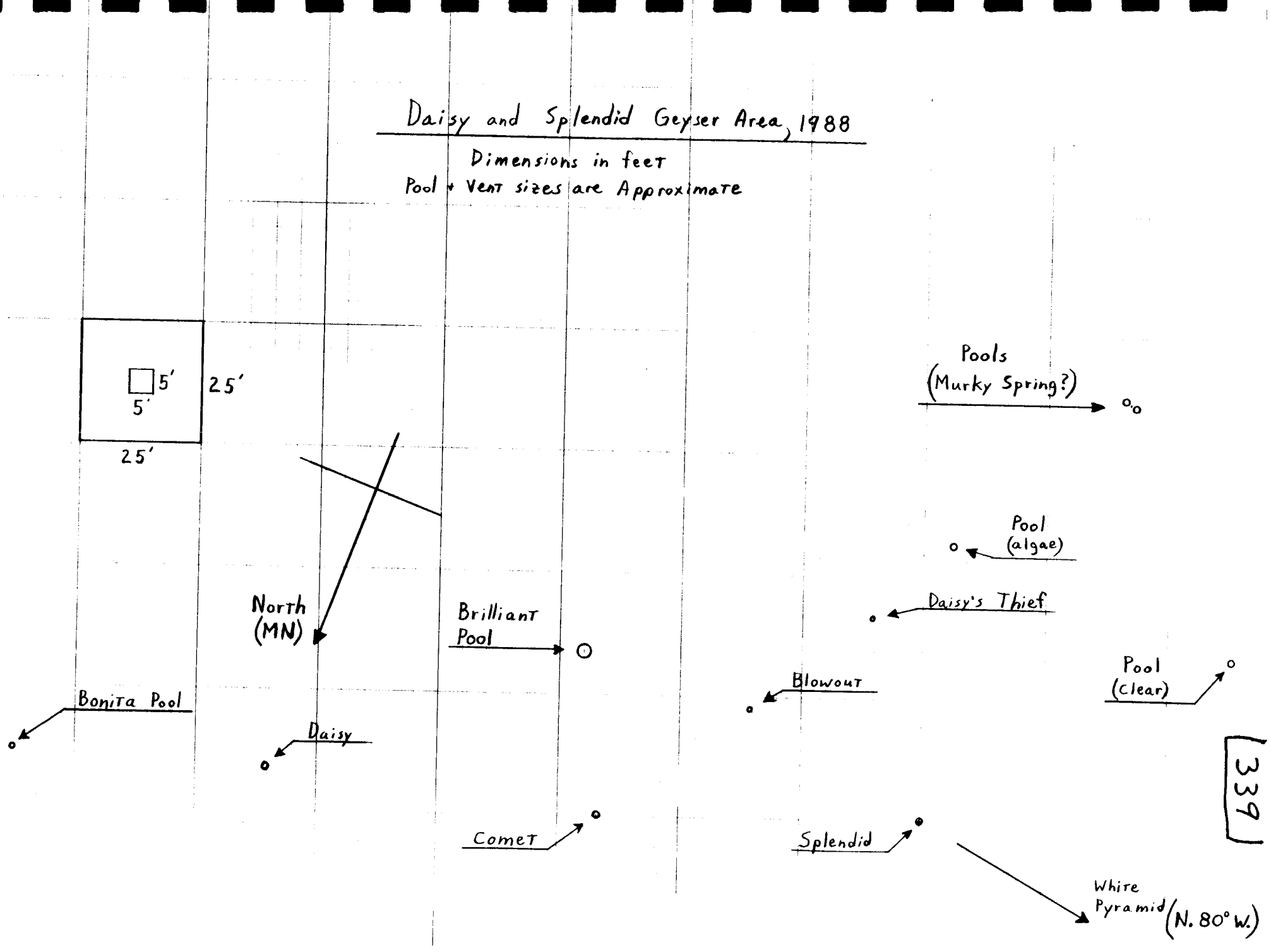

Grotto Geyser Area, 1988
Dimensions in feet
Pool + Vent sizes are Approximate
50'
10'
10'
50'
Marathon Pool
Vent (filled in)
Pool (Boiling)
Variable Spring
South Grotto Fountain
Grotto Fountain
Pools (clear)
Grotto Indicator Pool
North (MN)
Spa
Rocket
Grotto
Culvert
Persistent
Boardwalk location (Approximate)
Square Spring
W
W
N

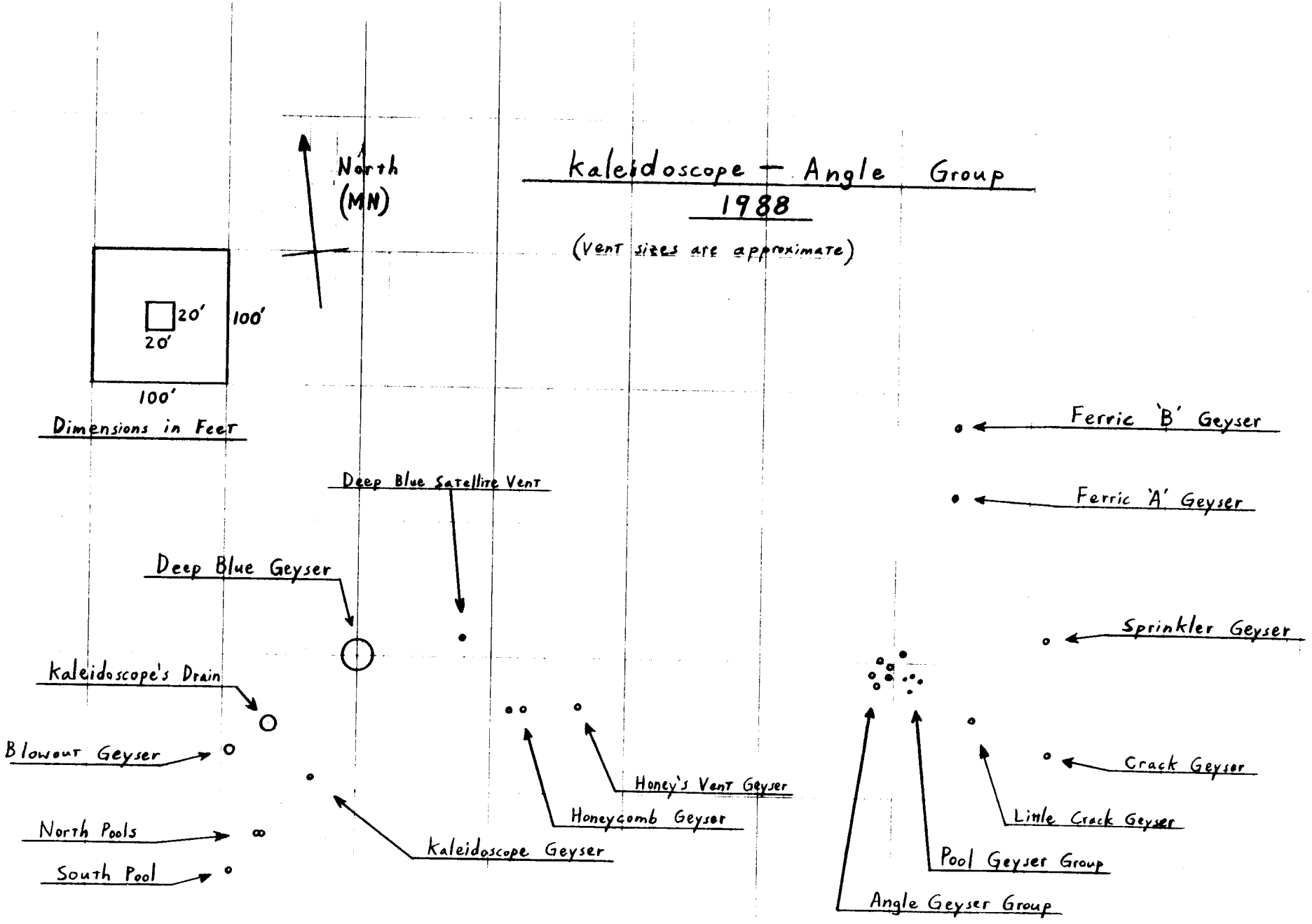

Fan + Mortar Geyser Area, 1988
Dimensions in feet
Pool + Vent sizes are Approximate
River Vent
Fan Geyser
Top Vent
Gold Vent
Main Vent
Angle Vent
Grand Canyon
4'
4'
20'
20'
Upper Mortar
Frypan
Spiteful Geyser
Lower Mortar
Bridge Vent
North (MN)
Fan Vent
(Buried Under Road)
Footpath Location (Approximate)
Pool (grass filled) (Norris Pool?)
Mud Pots
CWW

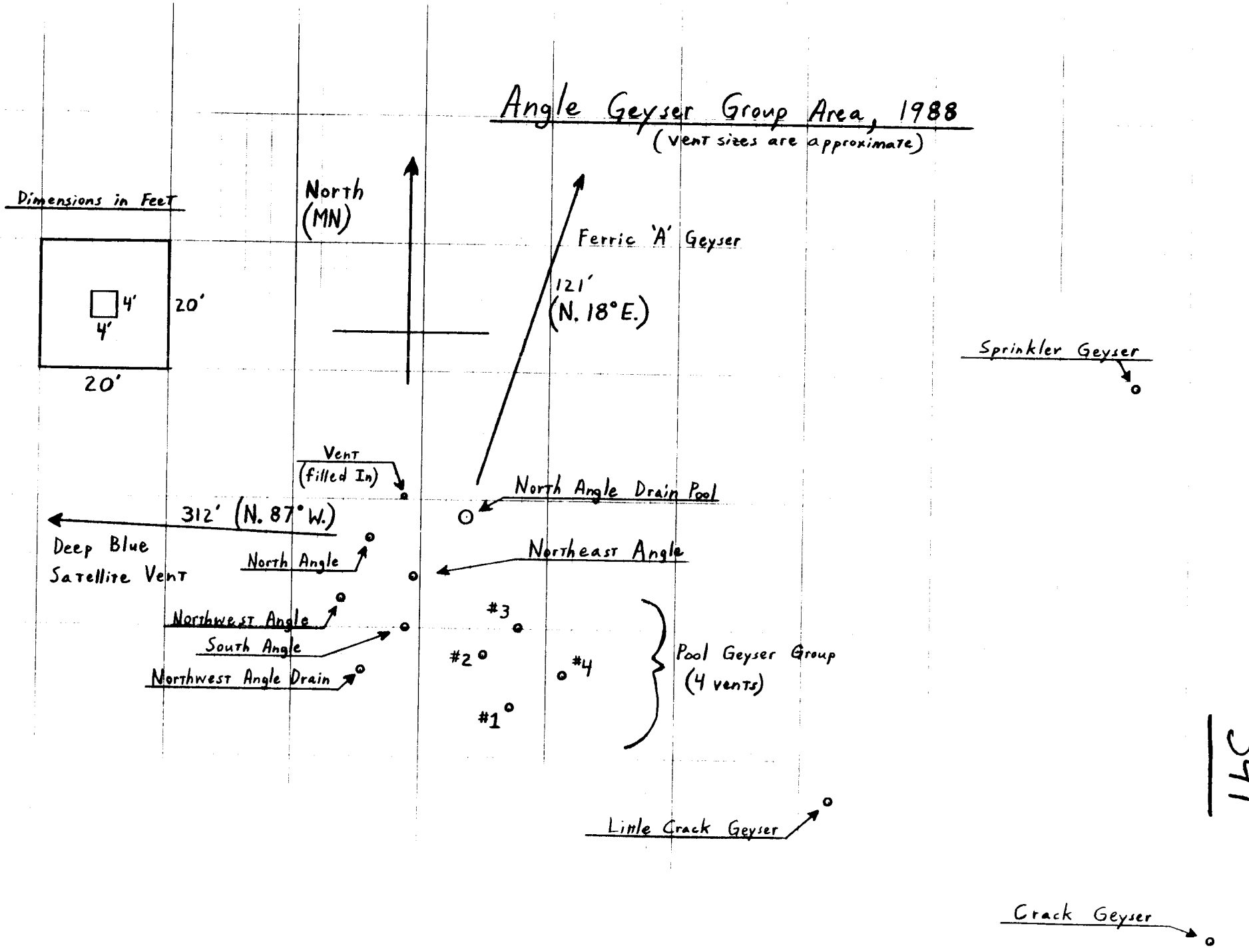
Daisy and Splendid Geyser Area, 1988

Dimensions in feet

Pool + Vent sizes are Approximate

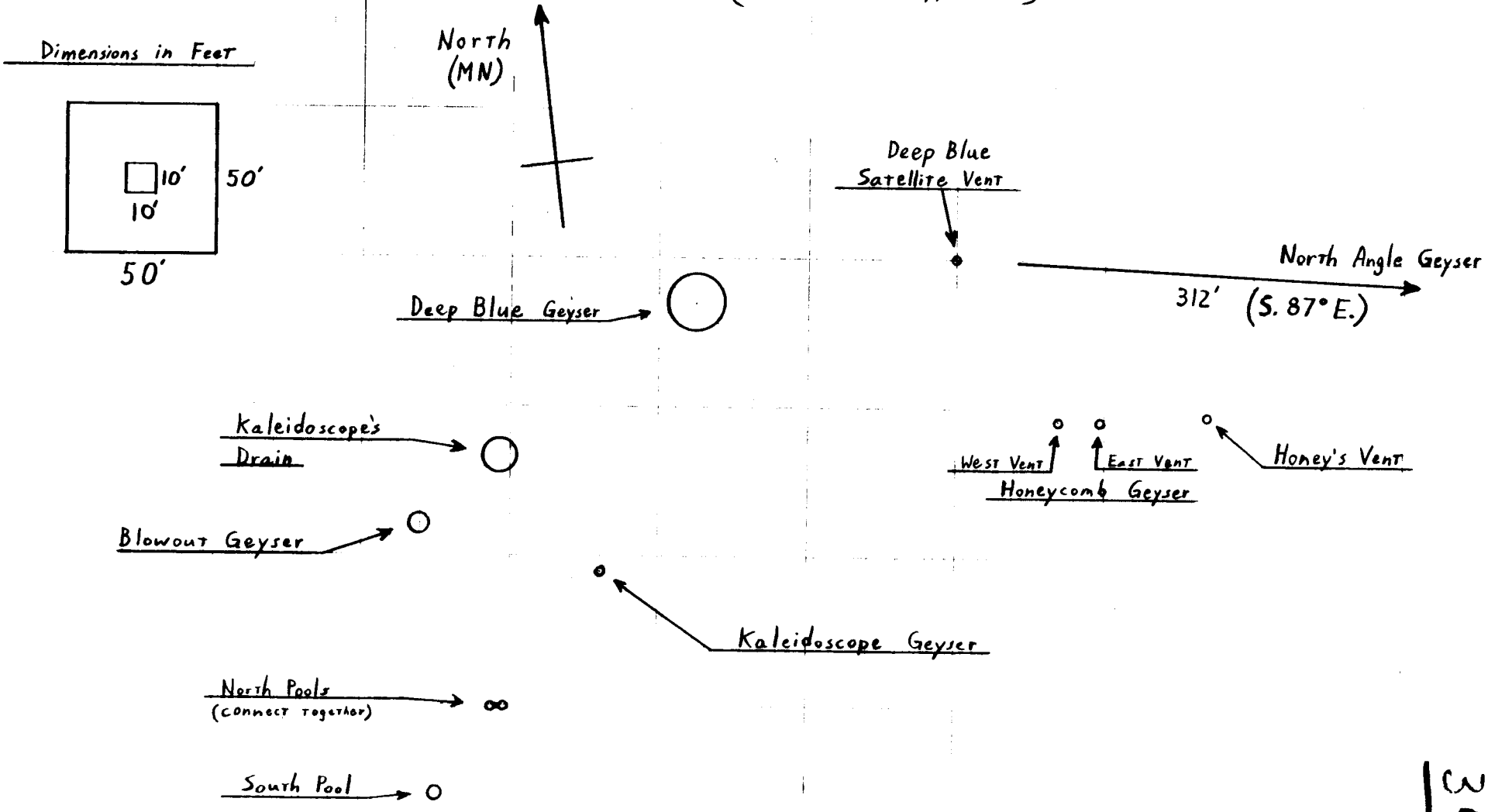



North (MN)
Kaleidoscope – Angle Group
1988
(Vent sizes are approximate)
20'
20'
100'
100'
Dimensions in Feet
Ferric 'B' Geyser
Ferric 'A' Geyser
Deep Blue Satellite Vent
Deep Blue Geyser
Sprinkler Geyser
Kaleidoscope's Drain
Blowout Geyser
Crack Geyser
Honey's Vent Geyser
Honeycomb Geyser
Little Crack Geyser
North Pools
Kaleidoscope Geyser
Pool Geyser Group
South Pool
Angle Geyser Group

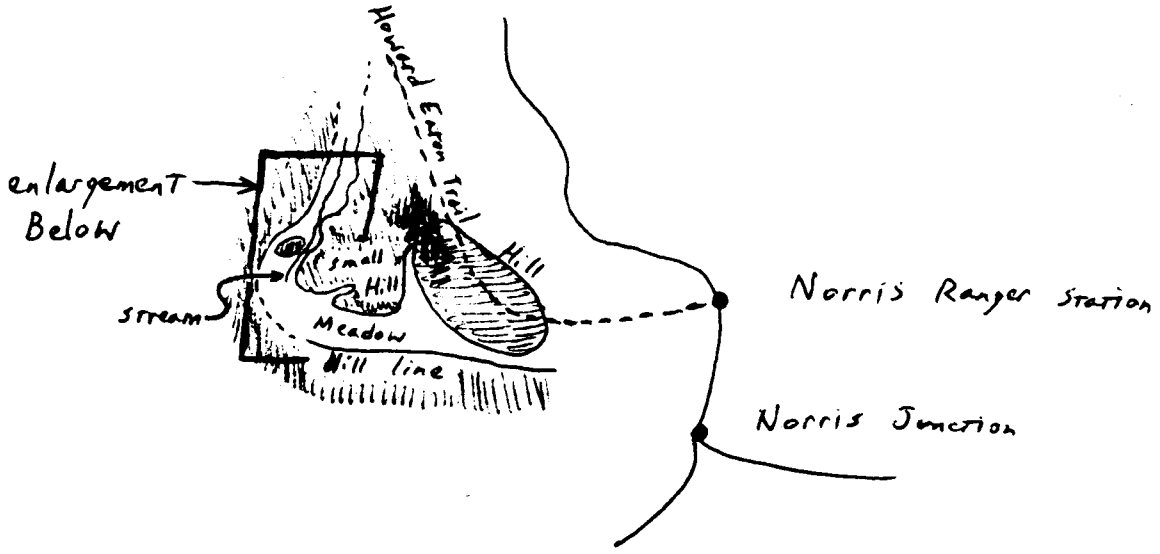

Angle Geyser Group Area, 1988
(vent sizes are approximate)
Dimensions in Feet
4'
4'
20'
20'
North
(MN)
Ferric 'A' Geyser
121'
(N. 18° E.)
Sprinkler Geyser
Vent
(filled In)
North Angle Drain Pool
312' (N. 87° W.)
Deep Blue
Satellite Vent
North Angle
Northeast Angle
Northwest Angle
South Angle
Northwest Angle Drain
#3
#2
#4
#1
Pool Geyser Group
(4 vents)
Little Crack Geyser
Crack Geyser

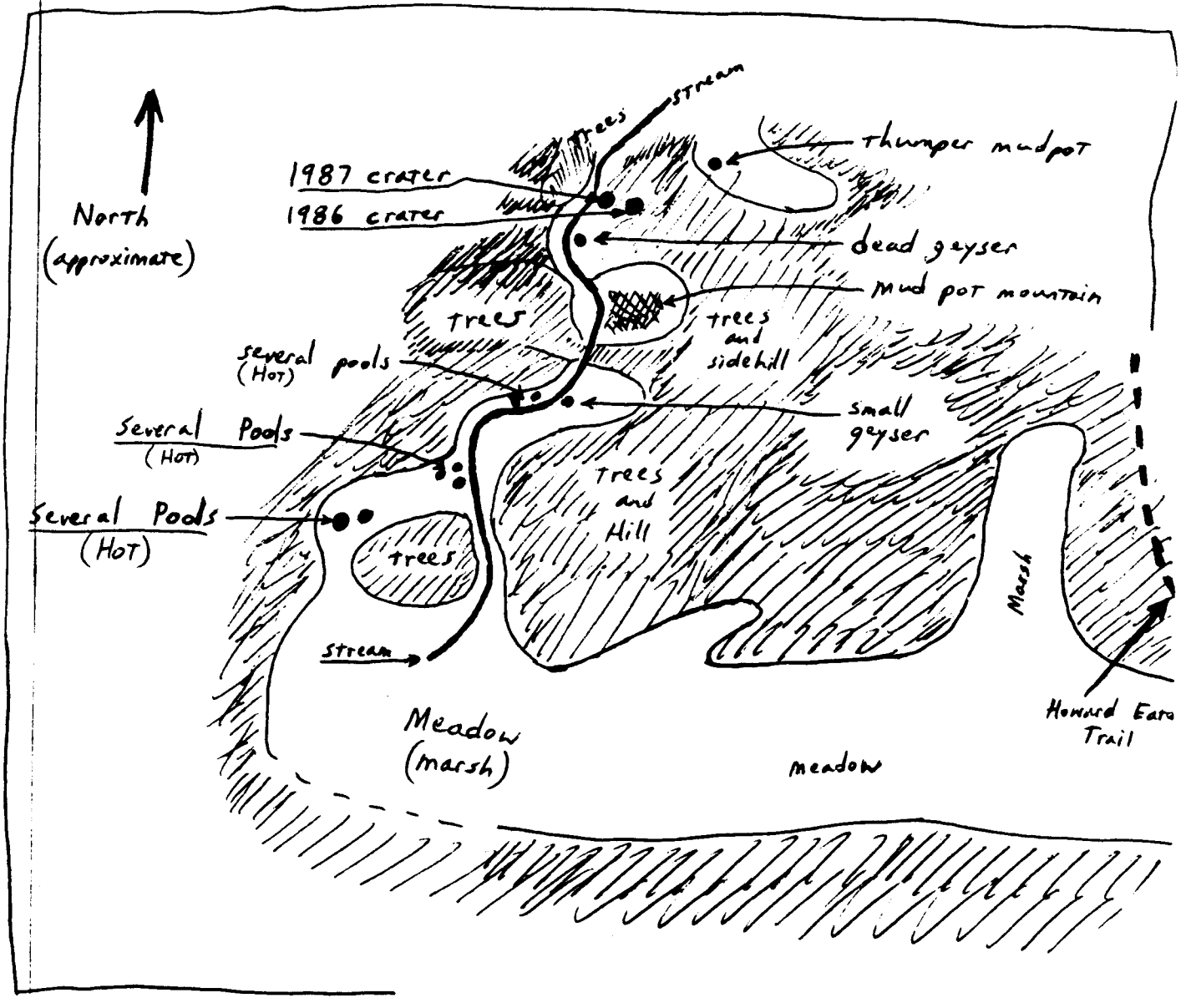
Kaleidoscope Geyser Area, 1988

(Vent sizes are approximate)



Basin Northwest of Norris Basin





655
709
732
757

Giant Eruption 6-28

Hot Periods

date	time	
[redacted]	[redacted]	
7-9	1600	
7-15	Earthquake 0815	R = 3.5-4
7-19	0300	
7-21	0800	
7-23	0900	
7-25	1409	
7-27	1725	
7-29	2340	
7-30	0750	(minor)
8-1	0700 - 0900	(major)
8-1	1130	(minor)
8-6	1034	
8-8	2208	
8-10	1200	
8-10	1800	(minor)
[redacted]	[redacted]	

to page 633

Fantail 1225 – Major eruption in last 1-2 weeks
- all markers washed (and stones too)
- killed grass west + south of vent
- constant superheated boiling
- occurring today; also small fluctuations in good level (smaller than previously noted)

Artemisia 1229 (E)

Giant 1753 – Major hot period (mike)

Giant 2280 – Related markers

[illegible] – liquid visible in over half the vents

Giant Hot period	Geyser Eruption assumed	observed	* = First eruption after Marathon ('long' duration Grand FTN 'short' duration Grand)
0700 (major)		1230 (8-11)	Marathon
1336 (minor) / 1753 (major)	1300	≈ 1400 (8-12)	
	2000	(8-12)	
*0600 (major)	0230 (8-13)	(8-13)	51
	0900	0821 (8-13)	
1915 (minor)	1500	1514 (8-13)	Marathon (0610 ends 8-14)
1145 (major)		*1756 (8-14)	
		0728 (8-15)	47
1848 (minor)		1359 (8-15)	Marathon 0400 done 8-16
1420 (major)		(8-16)	
		*1833 (8-16)	
	0720 (8-11)	0636 (8-17)	48
		[illegible]	Marathon 0500 again end 8-18
1440 (major)		1405 (8-18)	
2210 (minor)		2005 (8-18)	

→ TO 655

Giant Hot Period	Grotto assumed	Eruption observed
From Page 633 → 2210 (minor)		2005 (8-18)
(11) 0910 (minor)	0230	44
	0900	(8-19)
		1004 (8-19) Marathon
52 (33) → 1830-1930 (major)		1003 (8-20) Marathon ends
		(8-20) 72
20 (20) → 1440 (Major)		1052 (8-21) ← First eruption since 1004 (8-19)
(5) 1930 (minor)	0100 (8-21)	1745 (8-21)
		(8-22)
48 (16) → 1133 (Major)		0959 (8-22) Marathon
	(8-23)	1215 (8-23) ← First since 0959 (8-22)
	1830	(8-23)
Earthquakes 1034 (8-24) In Park	0100	56
	0730	
25 → 1234 (major)	1000	0923 (8-24) ← No marathon — spa overflow continues
		(8-24)
Earthquake 1606 (8-24) Felt at Jackson		1315 (8-24)
(Possible end at 0500 8-25)		1843 (8-24) Marathon
		1205 (8-25) Marathon 17
		1102 (8-26, eruption ends)
	1900	(8-26)
		(8-27) 50
66 → 0237 (minor)	0130	
0404-0730 (major)	0800	0824 (8-27) ends 1012
		1934 (8-27) Probable Marathon
27 → 0927 (Major)	(8-28)	
		1251 (8-28) (First since 1434) No
	1430	(8-28)
	0200	49
	0830	
30 → 1547 (major)	(8-29)	1034 (8-29) Marathon
24 → 1604 (major)		0400-0700 (8-30) (eruption ends) 49
		1914 (8-30) (first since 1034)
	0800	
	1030	1121 (8-31) Marathon
40 → 0800 (major)		2400 approx (8-31) ends Marathon
1125 (minor)	(9-1)	
1600 (minor)		1145 (9-1) First since 2400
1705 (minor)		
	1800	1729 (9-1)
0304 (minor)	2400	
	0630	0635 (9-2)
	1300	1215 (9-2) No Marathon
33 → 1657 (major)	(9-2)	
?	1830	1830 (9-2) 72
	0400 Note shift to longer intervals	
	1100	1117 (9-3) Marathon
		2400 (9-3) ends marathon
47 → 1534 (major strong)	(9-4)	1014 (9-4) First since 1117 (9-3)
		1829 (9-4)
	0030	(9-5) 43
	0630	0610 (9-5) Marathon
41 → 0838 (Major Weak)		(9-6)
		1411 (9-6) First since 0630 9-5
		1618 ends

→ to 709

From 655 → Giant Hot Period

Grotto Eruption

	assumed (approx, Not Predicted)	observed
41		
41		
21 → 0530 (Major)	2200	1411/1615 (9-6) — 48
	0600 (9-7)	
24 → Early AM (Major) (0600 Assumed)	(9-8)	0618 (9-7) Marathon
		1208 (9-8) (First since 0618)
		1819 (9-8)
25 → 0700 approx (Major)	0230 (9-9)	(9-9)
	0900	0856 (9-9) — 57
21 → overnite (After Major) (0300 assumed)	(9-10)	1503 (9-9) Marathon
		Grotto Not seen on 9-10
16 → 1852 (Major) — Massif Heavy overflow	(9-10)	
	0600 (9-11)	← Possible other(s) In here
		1233 (9-11)
		2009 (9-11)
	0240 (9-12)	
		0943 (9-12) — 72
X 48 → Giant Erupts		1613 (9-12) Marathon I = 3 days
1847 (Massif Function)	(9-12)	
	No eruption (0800-1800) (9-13)	60
	Other eruptions ??	
	0600 (9-14)	(9-14) (Just ended 0900)
		1144 (9-14)
	(9-15)	1703 (9-14)
	0900	0900IE (9-15) Marathon — 48
		0911 (9-16) (First since 0400)
	(9-17)	1802 (9-16)
		0900IE (9-17) Marathon
		1055 (9-18) (First since 0300)
	2600 (9-18)	2016 (9-18)
7d 7h → overnite (major) (0200 assumed)	0500	0830IE (9-19) Marathon, assumed
		(9-20)
	0500	(9-20)
		57
	2300 (9-20)	1412 (9-20)
	0800	0900 approx (9-21)
30 → 1820 (Major)		1656 (9-21) Marathon
		(9-21)
28 → overnite (major) (2200 Approx)	(9-22)	1850 (9-22) (First since 1656)
	0200	(9-22)
	0800	0813IE (9-23) — 45
	1600	1411 (9-23) Marathon
1443 (minor)		(9-23)
	2300	(9-24) (First since 1411)
52 → 0200 (major) approx.		(9-25)
	0600	0915 done (9-25) — 58
		1257 (9-25)
(2000) (active overnight (Apparently very short MARATHON))		(9-25/9-26) SHORT MARATHON
44 → overnite (major) (2200 Approx.)		1735 (9-26) (First since 0930, 9-26)
	2400	(9-26)
	0600	(9-26)
14 → 1200 (Major) (Possible Massif Heavy Flow)		0740IE (9-27)
	1500	(9-27)
	2300	(9-27)
	0700	0800IE (9-28)
24 → 1123 (Major)		
	1400	1312 (9-28)

TO 732

see 9-7 744

Recent eruptions
1955
1964 1963
1978
82
984
8-86
9-12-87
6-28-88
12-88

dk.
Suesane S.
Ann M.
Jennifer F.
Muller
L.
V.
Fritz
P.
W.
nielsen
Ryan
kids
Carolyn, Marshall
Schlosser
Leaking

Giant Hot Period — Grotto Eruption

From 709 → 52, 44, 14

Assumed	Observed	
24 → 1123 (Major)		(9-28)
1400	1312	(9-28)
2000	2022	(9-28) 85
0300	0408	(9-29)
24 → 1109 (Major)		(9-29)
1100	1136	(9-29) Marathon
39 → overnite (major) 0200 Assumed	2030	(9-30) First since Marathon
		(10-1)
0300		(10-1)
0930	1043	(10-1) 55
39 → 1730 (Major)	1905	(10-1) Marathon
1500	1900 TE	(10-2) Marathon
overnite (minor) 0000 assumed		(10-3)
1648 (Major)	1043	(10-3) First since 1500
1800		
0100		
0800	0915 ss	
60 → overnite (major) 0500 assumed		
Earthquake (10-5)		
13 → 1740 (major)	12[illegible]	
	1821	
0000		
19 → 1258 (major)	0651	
	[illegible]	
0000		
0700	0912, end	
1400	1413	(10-8) Marathon
45 → 0959 (Weak Major)		(10-8)
	1456	(10-8) First since N[illegible] 45
2100		(10-9)
0400		(10-9)
1100	1125	(10-9) Marathon (two)
49 → 1056 (Major) Strong overflow From Marathon	[illegible]	(10-10) First since 1125 49
24 → 1103 (Major)	1605	(10-11) Marathon
	[illegible]	
1530	[illegible]	(10-12) First since 1605
19 → Overnite (Major) 0600 Assumed	2235	(10-12) 40
		(10-13)
0800	0835 ss	(10-13) MARATHON
25 → 0700 (major)		(10-13)
1300-1500 (minor)	1359	(10-13) First since 0835 ss
	2153	(10-13) 45
21 0130-0800 (Major) 0400 Assumed		(10-14)
21 → 0049 (Major)	1108 ss	(10-14) Marathon
		(10-15)
0600		(10-15) First since 0500 10-14
	1238	(10-15)
2000		(10-15) 47
0400	0741, 1730 TE	(10-16) Marathon
52 → Overnite (Major) 0500 assumed		(10-17)
0830	0952 end	(10-17) First since 0400
	1608	(10-17)

To Pg. 757

From pg 732

Giant Hot Period

21
32

Grotto Eruption

	assumed	observed		
24 → Overnite (Major)	0500 Assumed	2300	(10-17)	58
		0600	(10-18)	
		1400	(10-18)	
32 → 1315 (Major)		1602 ss	(10-18)	MARATHON
			(10-19)	
		2400	(10-19)	First since 1400
		0630	0830 end (10-20)	
30 → 1855 (major)			1226 (10-20)	
			(10-20)	
			2018 (10-20)	69
		0330	0545 ss (10-21)	
			1128 (10-21)	
45 → 1618 (major)			1700 (10-21)	Marathon
			(10-22)	
		0400	(10-23)	First since 1700
			1152 (10-23)	
34 → Overnite (Major)	0200 assumed	1930	(10-23)	
			(10-24)	81
		0300	(10-24)	
		1030	1340 end (10-24)	
		1830	(10-24)	
47 → Overnite (major)	0100 Assumed	0200	1030 ss (10-25)	Marathon
			(10-26)	
		0200	(10-26)	First since 0900
		0900	1012 ss (10-26)	MARATHON
36 → 1309 (major)			1253 (10-27)	First since 0900
			(10-27)	
		1900	(10-27)	
		0100	(10-28)	46
			0600 (10-28)	Marathon
			1238 (10-29)	First since 0600
		1900	(10-30)	
66 → 0657 (major)		0100	(10-30)	
			(10-30)	
			0745 (10-30)	
			1430 (10-30)	

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