Effects of the 1959 Hebgen Lake earthquake
Yellowstone National Park
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EFFECTS OF THE 1959 HEBGEN LAKE EARTHQUAKE

Dianah GrubbWheeler
(GeoCorps Intern)
September 11, 2008

The largest earthquake in the Yellowstone National Park region occurred at 11:40 PM (MST) fifty years ago, August 17th 1959. The epicenter of the quake was near the border of Wyoming and Montana, close to the town of West Yellowstone and near the Junction of Highways 287 and 191. The earthquake was felt over a half million square miles (Ball, 1959). The quake caused the most destruction around its name sake, Hebgen Lake. Here, most of Highway 191 was damaged, causing huge cracks in the road (Figures 1, 2 & 3). Many people trying to flee the area in their vehicles became stranded as they fell into the cracks or crashed as they toppled off the edge of the fallen roadway (Figure 2). Luckily, none of these people were seriously injured. The injuries and deaths occurred with the massive Madison Landslide. The Madison River Landslide (Figure 4), that killed 28 people, deposited over 40 million cubic yards of rock, trees and debris, as it slid into the valley damming the Madison River (Ball, 1959) and created a lake, later named Quake Lake.

FIGURE 1: Photograph of fractured Highway 287: man inspecting damage. Hebgen Lake, Montana, Earthquake August 1959. (Colton, 2006)

FIGURE 2: Photograph of cars of fleeing vacationers stuck in fractured roadway. (Ball, 1959)

FIGURE 3: Photograph of a splay of the Red Canyon fault scarp created a 10-foot wall across the road. Photo by Carl Hayden, Salt Lake Tribune. (University of Utah, 2007)

FIGURE 4: Photograph of Madison Landslide by Earthquake Lake, somewhat east of drowned toe of slide. Photograph was taken after preparation of spillway had begun. Madison County, Montana. 1959. (McGregor, 1995)

Hebgen Lake tilted to the south, causing flooding of buildings and roads to the north (Figure 5 & 6) (Witkind, 1964). The earthquake also caused a tidal wave affect in the lake, causing waves of water to flow over Hebgen Dam. This led to false reports that the dam had failed. People worried that the reservoir water was going to flood the lower valley. Fortunately the dam held, however, after the Madison slide, as Quake Lake quickly filled with water, homes and parts of the highway were swept into the growing lake (Figures 7). A fault scarp ripped through the camp grounds to the north of the Madison River, below Hebgen Lake (Figure 8 & 9). The scarp was estimated to be about 12 miles in length, from the Duck Creek Highway (now called Duck Creek Road) junction to the Hebgen dam (Ball, 1959). Observing the fault scarp over the past 50 years has been vital to geologist researching how quickly this type of landscape weathers.

FIGURE 5: Photograph of south shore of Hebgen Lake left dry from tilting of lake. (University of Utah, 2007)

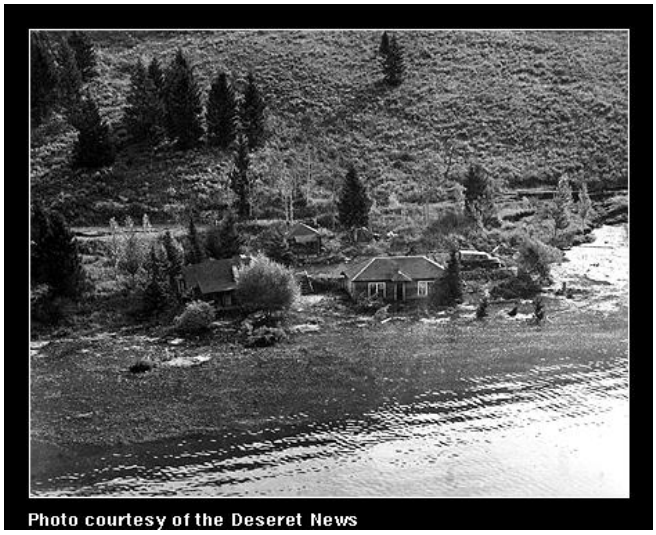

FIGURE 6: Photograph of Hilgard Lodge on the northeast shore. Note the northward tilting of Hebgen Lake. (University of Utah, 2007).

FIGURE 7: Photograph of roadway submerged by the growing Quake Lake. The lake was created by the damming of the Maddison river. (McGregor, 1995)

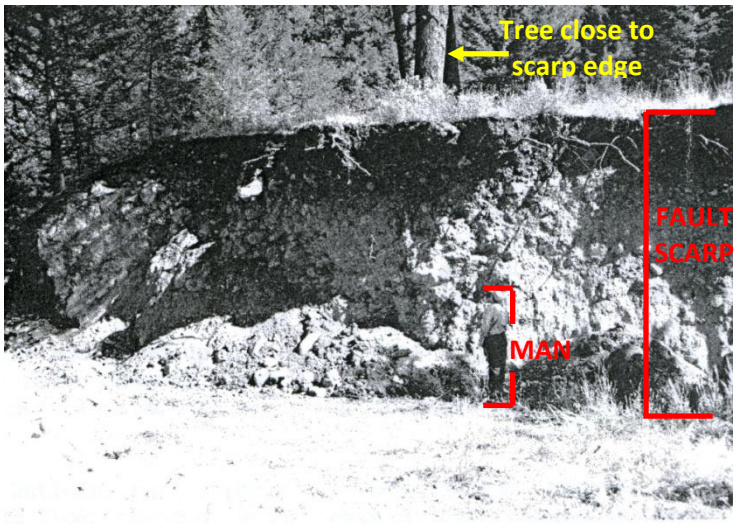

FIGURE 8: Photograph of fault scarp in campground below Hebgen Lake. Scarp is about 15 feet high. Note the tree close to the edge of the scarp and the steep angle of the scarp. (Ball, 1959)

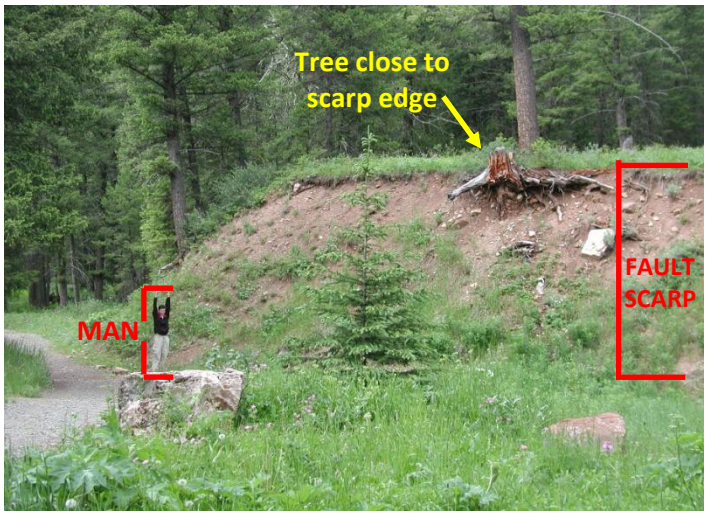

FIGURE 9: Photograph of fault scarp in campground below Hebgen Lake taken 2004. Note the tree stump close to the edge of the scarp, it is the same tree as seen in Figure 8. Notice how the steep angle of the scarp seen in Figure 8 has now curved out and is much less steep. (d'ALESSIO, 2004)

Yellowstone National Park was itself affected by this earthquake. The main areas affected were on the west side of the park with an estimated $2.6 million in damage to roads and $1.7 million worth of damage to buildings (Milstein, 1997). Buildings lost their chimneys (Figure 10), rock slides blocked the roads (Figure 11 & 12), and numerous geysers simultaneously erupted (Figure 13). Many rangers in the park, who handled the potential catastrophe, were relieved the quake occurred late in the evening. Had the quake occurred earlier in the day the rock slides and crumbling chimneys could have caused serious problems.

FIGURE 10: This is a photograph a collapsed chimney of the Union Pacific Dining Lodge in West Yellowstone, Montana. Chimneys collapsed on many buildings in Yellowstone National Park. A collapsed chimney at Old Faithful Lodge crashed through the roof and entered the dining hall. Had the quake come 4 hours sooner the hall would have been filled with the evening dinner crowd. (Witkind, 1964)

FIGURE 11: Photograph of Golden Gate in Mammoth Hot Springs, WY. Rock slides in Yellowstone National Park buried many segments of the roads on the west side of the park. (Boucher, 1959)

FIGURE 12: Photograph of ranger inspecting damage from small slide that dropped part of the road way and retaining wall away from the rest of the road. Parts of the roadway in Yellowstone National Park was damaged by fractures and small slides. Note the large boulders and trees blocking the roadway (Boucher, 1959)

FIGURE 13: Photograph of geysers in Yellowstone National Park simultaneously erupting. Many erupted with the first shock of the earthquake. (Boucher, 1959)

The rock slides that blocked the roads occurred at the Firehole Canyon, Gibbon Falls, Obsidian Cliff, Silver Gate, Virginia Cascades, between Madison Junction and the West Entrance, and the largest at Golden Gate (Figure 11) in the Mammoth Hot Springs area (Motherspaugh, 1959). Rock slides at Gibbon Canyon caused the most road damage in the park (B). "The road through Firehole Canyon was covered at two places by slides more than 10 feet deep" (Motherspaugh, 1959). Other rock slides occurred in the park, many from Mt. Jackson, and larger ones from Mt. Holmes and Mt. Everts.

The 1959 earthquake triggered slides on Mount Everts, a photograph taken in 1958 shows vegetation growth on the area of the 1959 rock slide (Figure 16). After the 1959 rockslide on Mount Everts the vegetation is no longer present, this can be seen in photographs taken in 1970 (Figure 18) and 2008 (Figures 15, 17, and 19). A photograph from 1878 (Figure 14) conspicuously shows little vegetation on the same area as the 1959 rock slide. Comparing figures 14 with figures 16, 17 and 18, it seems that some type of event occurred in the rock slide area prior to 1959. With further investigations, sampling and testing of living and dead trees on Mount Everts for evidence of rock slide activities prior to 1959 may explain the lack of vegetation in the 1878 photograph.

Most of the thermal features in the park were affected only briefly by the earthquake. On 17 August 1959, water ebbed from a few inches to several feet in 363 springs. There was a noticeable increase in activity in 333 others. Only 57 seemed to be normal, but most of these underwent alteration in function during the weeks following the earthquake (Marler, 1960) (Appendix A and B) (Marler, 1964).

Of the thermal springs that showed activity after the earthquake, 160 had no previous record of eruption (Marler, 1964). Many geysers simultaneously erupted with the first major shock wave of the earthquake. Others erupted shortly afterwards. Many of the changes to the geysers' eruption cycles returned to normal by January of 1960 (Marler, 1964). "Giantess

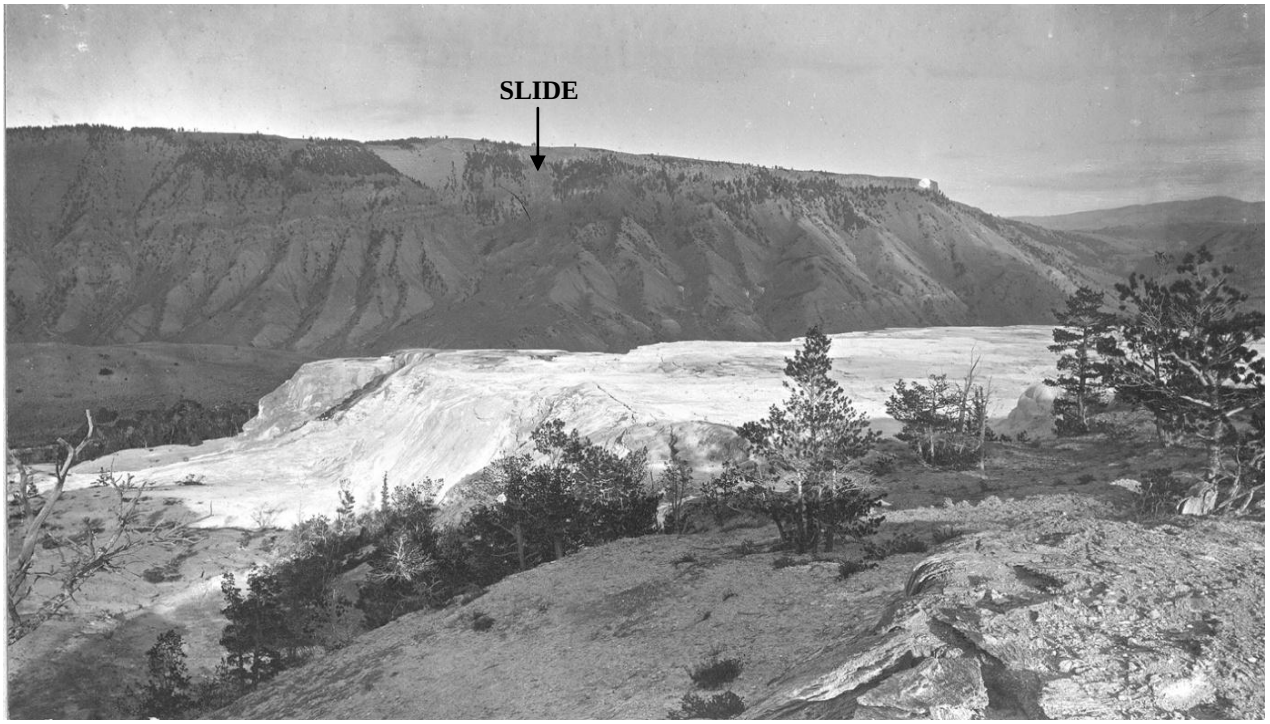

FIGURE 14: This photograph facing northeast was taken during the Hayden Survey in 1878. The light colored area marked by "SLIDE" is the area focused on in the comparison. Based on the lack of vegetation, this area appears to be like that of today's photo (Figure 15). Today's photo shows the area of the 1959 Hebgen Lake Earthquake induced rockslide. (Jackson, 2006)

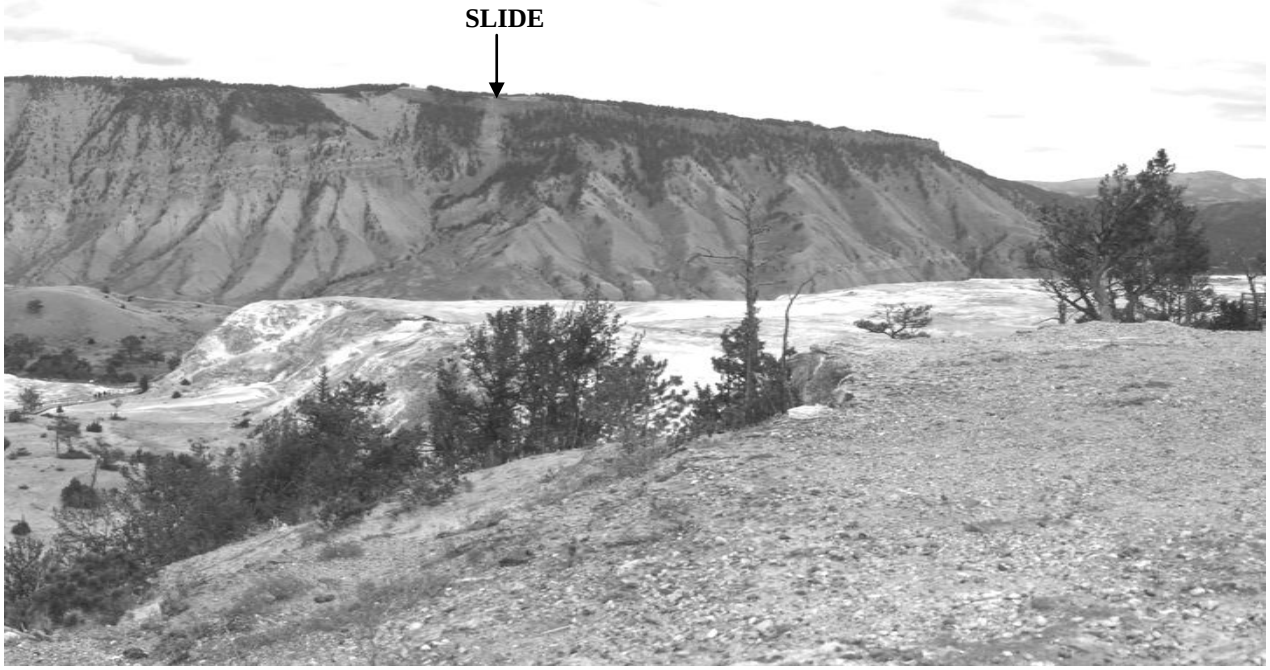

FIGURE 15: This photograph facing northeast was taken September 2008. The area marked y "SLIDE" is the area of the 1959 Hebgen Lake Earthquake induced rockslide. This photograph shows an area with no vegetation. This is seen in the 1878 photograph (Figure 14) and the 1970 photograph (Figure 18). (GrubbWheeler, 2008)

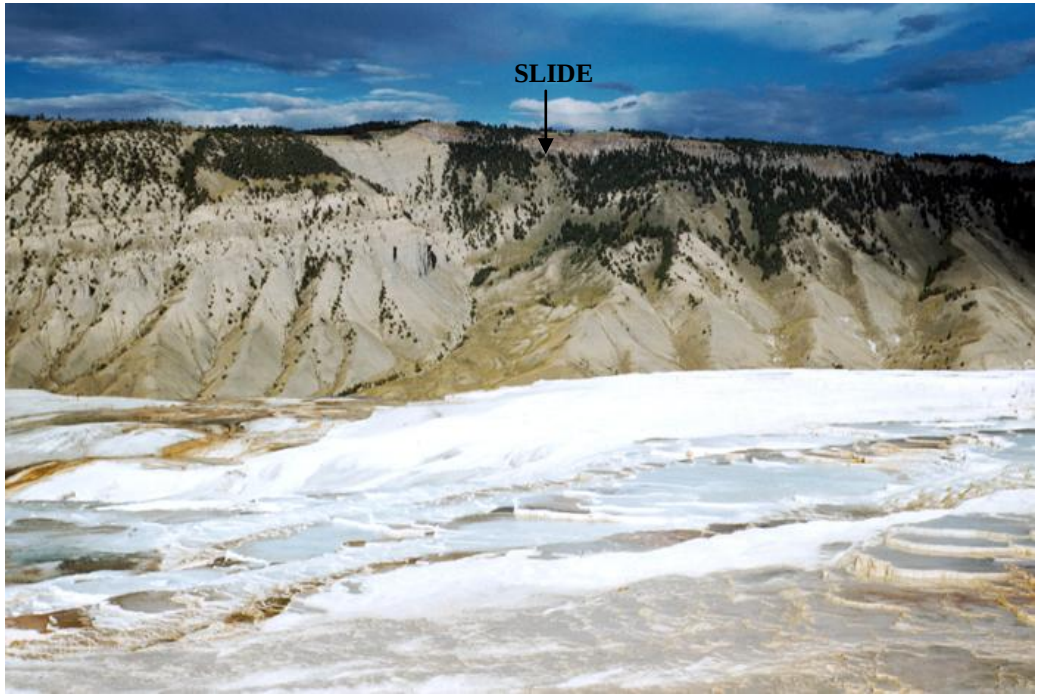

FIGURE 16: This photograph was taken in 1958, a year before the Hebgen Lake Earthquake. The area marked by "SLIDE" is the area focused on in the comparison between the photographs. The presence of vegetation prior to the 1959 quake induced rockslide is seen in this photograph. This vegetation is lacking in a 1970 photo (Figure 18), the 2008 photo (Figure 15, 17, and 19) and the 1878 photo (Figure 14). (Hamilton, 2006)

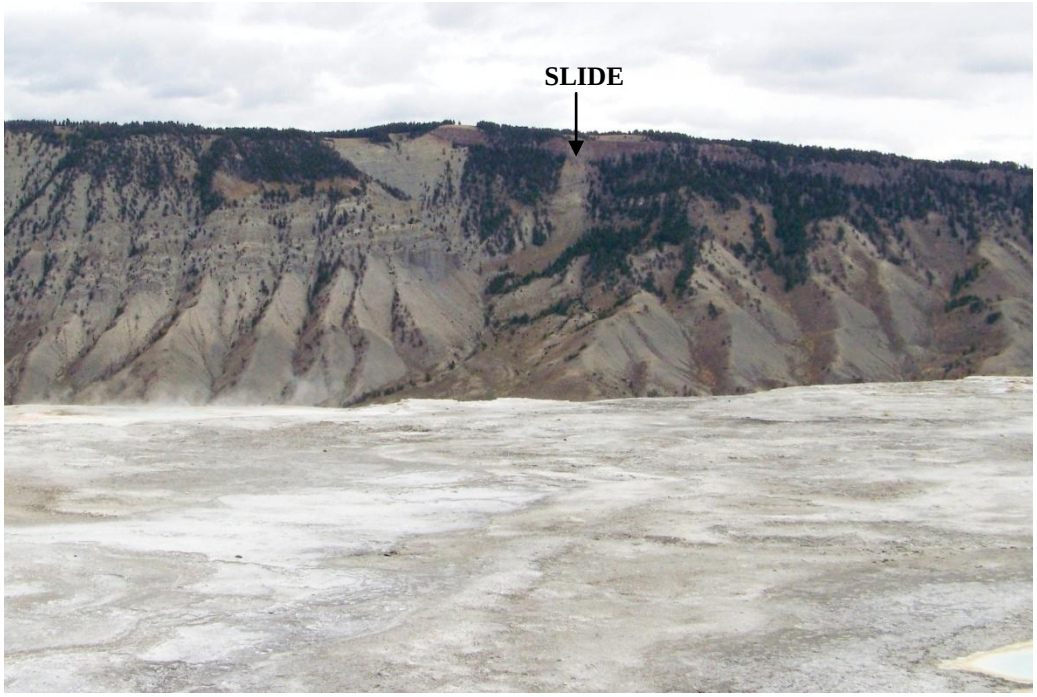

FIGURE 17: Mount Everts facing northeast taken September 2008. (GrubbWheeler, 2008)

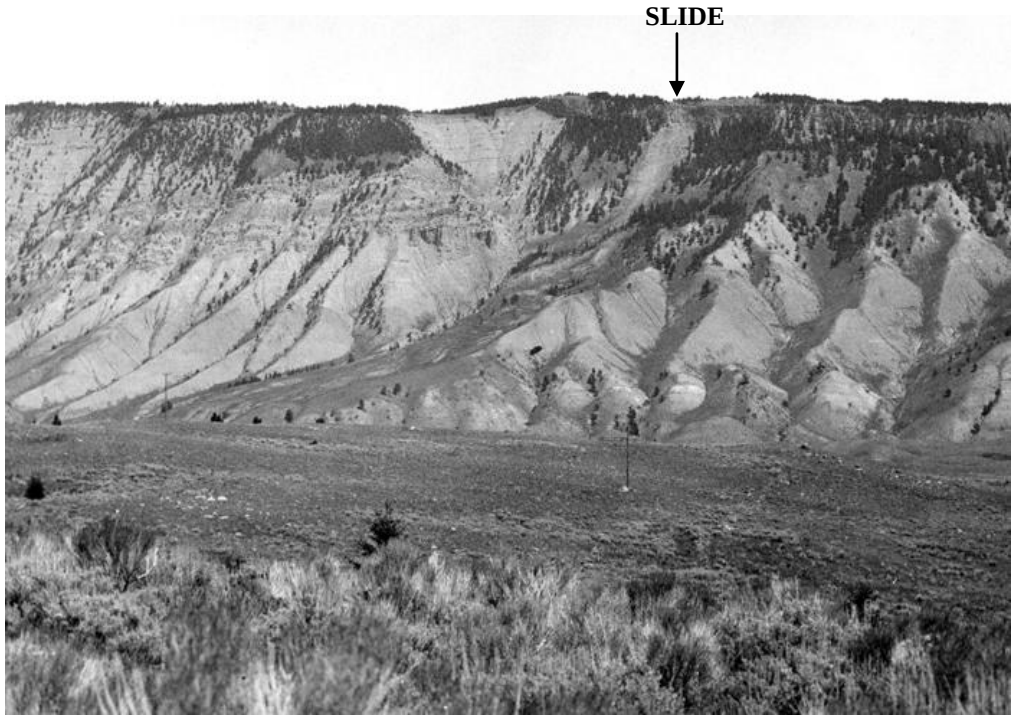

FIGURE 18: Photograph taken in 1970, 11 years after the Hebgen Lake Earthquake induced rock slide of Mount Everts, facing northeast from south of Mammoth Hot Springs. Note the lack of vegetation between this figure and Figure 16, taken in 1958. (Stacy, 2006)

FIGURE 19: Photograph taken September 2008. The lack of vegetation compared to Figure 18, taken in 1970, the vegetation removed by the 1959 quake induced rock slide still persist. (GrubbWheeler, 2008)

Geyser started simultaneously with the quake and erupted continually for more than 100 hours. Its usual duration had been 30 hours or less. Economic and Cascade Geysers, which had been dormant since the 1920s, are now active." (Motherspaugh, 1959) "As of January 1960, only one of the big geysers seems to have been affected adversely. It is certain that the Grand Geyser erupted immediately after the earthquake, but it has been dormant since (1964)." (Marler, 1964). Today Grand Geyser periodically erupts, however, it has not returned to its original eruption pattern prior to the earthquake (Table 1). A new geyser, named Earthquake geyser, formed west of the Fountain Group near Gentain Pool. This geyser "expelled water over 100 feet high. This activity lasted just a few weeks after the earthquake", (Marler, 1960). In the Fountain Paint Pots, new thermal vents opened in the parking lot (Figure 20) and higher on the surrounding hill side.

FIGURE 20: The earthquake caused new features to form in around Artist Paint Pots. Photograph of thermal feature breaking through the asphalt of the Artist Paint Pots parking lot. (Boucher, 1959) (YNP Geologists believe this photograph shows Fountain Paint Pots.)

Earthquakes have been reported in the park since 1872, when Yellowstone National Park was founded. Though the park has 1000 to 3000 earthquakes a tear (Volcano Questions & Answers, 2008), seismic records show that strong earthquakes occur only about once every 10 years. The last major earthquake along the Hebgen Fault was on November 23, 1947 (Marler, 1960).

Rockslides are common in the park and have occurred for many years based on the lichen coved boulders that lay at the mountains' base. Old fractures in the geyserite of geysers and springs were probably created by previous earthquakes (Marler, 1960). The changes to the geysers alone suggest that their existence started with an earthquake. Changes to the underground piping that feeds the geysers and hydrothermal springs with water are ever changing and easily altered with earthquakes.

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APPENDIX A

Summary of Characteristics of Geysers affected by Hebgen Lake Earthquake

Marler, 1964

TABLE 1 —*Summary of characteristics of geysers affected by Hebgen Lake earthquake* (Marler, 1964)

[U, undetermined; NM, not readily measurable; PF, periodic flow]

Name	Observations prior to Aug. 17, 1959						Observations after Aug. 17, 1959					
	Eruption frequency	Discharge 1959 (gpm)	Normal height of eruption (ft)	Temperature (° F)		Characteristics	Date	Eruption frequency	Discharge (gpm)	Normal height of eruption (ft)	Temperature (° F) September 1959	Characteristics
				September 1951	Summers 1958–59							
UPPER GEYSER BASIN												
Daisy Group:												
Daisy	128 min	[1] 1,250	75–80	196	196	Plays at angle; has preliminary overflow.	Aug.–Dec.	58 min	[1] 1,250	75–80	200	Earthquake doubled frequency of activity; no preliminary overflow.
Comet	4 min	0	4–5	200	200	Water of eruption falls into crater.	do	Constant	0	4–5	202	Water level ebbed 12 in.
Splendid	Infrequent	[1] 4,160	125	200	200	Series of eruptions when in active phase.	do	One eruption	[1] 4,160	125	202	Played following quake, increased boiling since.
Daisy's Thief	do	[1] 80	20	199	199	When active, eruption precedes and stops Daisy.	do	None	0	0	200	12-in. ebb in water level.
Morning Glory Group:												
Fan	do	8	100–125	199	199	Several vents in cracked sinter.	do	do	10	0	202	Increased boiling and temperature.
Mortar	do	U	30–40	199	199	Plays in concert with Fan.	do	do	0	0	200	Water in crater level higher; hotter.
Sentinel	Dormant	25	0	200	200	Constant boiling	do	do	25	0	202	Erupted after quake.
Grotto Group:												
Riverside	7 hrs 32 min	U	75–80	200	200	Plays at angle, preliminary overflow.	do	6 hrs 28 min	U	75–80	200	5- to 6-hr intervals first few days following earthquake.
Link	Dormant	0	0	202	157	Had ebbed below overflow.	do	None	35	0	163	Murky; increased temperature and discharge.
Culvert	Steady	0	2	198	200	Steady boiling from road shoulder.	do	Steady	0	3	202	Increased temperature and vigor of boiling.
Grotto and Rocket (function as single unit).	8 hrs	[1] 470	10–50	200	200	Active about half of the time; longest eruption 12 hrs.	do	4–10 hrs	[1] 470	10–50	201	Active at times for more than 30 hrs.
Grotto Fountain	8–24 hrs	[1] 430	50	200	200	Precedes Grotto's eruptions.	do	Occasional	[1] 430	50	198	Rejuvenated, 8 to 24 hrs, in October.
Spa	8 hrs	[1] 45	1-ft surge	182	183	Action follows Grotto	do	4–10 hrs	[1] 45	1	183	Murky following earthquake.
Giant Group:												
Giant	Dormant cycle.	0	0	203	202	Periodic cycles	do	None	0	0	203	More sloshing in crater since earthquake.
Catfish	Dormant	0	0	200	198	Active and dormant cycles.	do	Dormant	0	0	202	More vigorous boiling.
Mastiff	do	0	0	204	203	Active when Giant is hot.	do	do	0	0	205	Increased boiling.
Turtle	do	0	0	199	200	Active during active cycle of Giant.	do	do	U	0	200	Periodic overflow following earthquake.
Oblong	6–8 hrs	U	20	197	198	Voluminous discharge	do	3–5 hrs	NM	20	200	Murky; more frequent activity.
Black Sand Basin:												
Whistle	Dormant	.04	0	199	143	When active has long and violent steam phase.	do	Dormant	.05	0	144	Murky first week after earthquake.
Cliff	Infrequent	NM	25–30	198	197	Three eruptions in 1959	do	Active daily	NM	25–30	200	Erupts 3- to 10-hr periods daily.
Spouter	Near constant	80	3–4	197	198	Erupts most of the time	do	Nearly constant.	80	3–4	200	Increase in temperature; murky Aug. 18.
Castle Group:												
Castle	14–17 hrs	U	75–100	200	200	Steam phase eruptions	do	4–9 hrs	U	75–100	201	Eruptions about twice as frequent.
Sprinkler	80–100 hrs	do	3	194	194	Splashing eruptions	do	56–60 hrs	U	3	198	Increased frequency.
Deleted Teakettle	Dormant	0	0	200	200	Rarely erupts	do	Dormant	6.5	25	199	Erupted following earthquake; flowing.
Churn	do	0	0	151	155	do	do	Occasional	[1] 3	Boiling eruption	161	Did not rejuvenate until November.
Sawmill	2–3 hrs	[1] 190	20–40	167	189	Plays at about time of overflow.	do	1–3 hrs	[1] 190	20–40	194	Erupted almost continuously first 4 days following earthquake.
Tardy	do	[1] 25	6–10	194	194	Connected with Sawmill.	do	do	[1] 25	6–10	196	Increased activity following earthquake.
Spasmodic	U	[1] 45	1–2	199	199	Boiling-type activity	do	2–4 hrs	[1] 45	6–10	203	Boiling more vigorous.

Table 1 (Marler, 1964)

Grand Group:												
Old Tardy	Infrequent	[1] 35	6	201	200	Jet-type eruption	do	1 or more times daily.	[1] 35	6	202	Increased activity since earthquake.
Bulger	Daily	[1] 30	6–8	198	199	do	do	do	[1] 30	6–8	202	More frequent activity.
Triplet	8–12 times daily.	[1] 25	2–3	184	185	Boiling-type eruption	do	Dormant	6 PF	0	182	Dormant since earthquake.
Grand	3 times daily	60 (quiet phase)	150–180	169	176	Rocket-type eruption	do	do	70	0	165	One eruption following quake; increased flow.
Turban	15–25 min	do	3–6	196	197	Boiling-type eruption	do	do	25	1	187	Partial rejuvenation since September.
Economic	Dormant	0	0	144	154	Jet-type eruption	Aug.–Sept. 15	5–20 min	7.5	6–10	200	Dormant since Sept. 15.
Geyser Hill Group:												
Infant	Only with Giantess.	.4	1	199	198	Boiling-type eruption	Aug. 17	Played for 100 hrs.	3	2	201	Has played occasionally since Aug. 17; usual level −3 in.
Giantess	Infrequent	U	20–50	200	198	Rocket-type eruption	Aug.–Dec.	1 eruption	U	20–150	200	Triggered by earthquake, eruption lasting 3 times normal duration; increased boiling; inactive in January 1960.
Vault	5–7 days	1.3 (quiet phase)	8–10	198	184	Dome-type eruption	Oct.–Dec.	Most days several eruptions.	1.3 in quiet phase	8–10	197	Inactive Aug. and Sept.; marked rejuvenation since September.
Cone	Dormant	0	0	193	191		Nov.–Dec.	Several daily	U	25–30	194	No previous record of activity.
Aurum	Cyclic	0	0	201	201	Was in dormant period	Aug.–Dec.	U	35	12–15	201	Rejuvenated to active geyser by earthquake.
Sponge	45 sec–1 min	[1] 3	.5	202	202	Boiling-type eruption	Aug.–Sept.	Dormant	0	0	200	Water ebbed 6 ft; no activity.
							Oct.–Dec.	45 sec–1 min	3	2/3	203	Increased boiling.
Model	Dormant	U	3–5	192	192	Jet-type eruption	Aug.–Dec.	U	U	3–5	194	Occasionally active since quake.
Lion	4 times weekly.	do	50–60	201	200	do	Aug.–Nov.	Very infrequent.	U	50–60	200	Fewer eruptions following earthquake, partial rejuvenation in December.
Big Cub	Dormant	do	40	200	200	do	Aug.–Dec.	Dormant	0	0	203	Water level, +4 in.; increased boiling.
Lioness	do	do	20–30	200	200	Dome-type eruption	do	do	0	0	201	Water level, +6 in.; increased boiling.
Little Cub	1–4 hrs	1	2 to 3; occasionally 10	200	200	Jet-type eruption	do	10 min to 4 hrs	1.5	3–10	200	More 10-ft eruptions than preceding earthquake.
Depression	2–3 hrs	[1] 62	3	182	186	Splash-type eruption	do	1–2 hrs	[1] 62	3	188	Increased frequency of activity.
Beehive	1 to 2 times weekly.	NM	150–180	203	203	Powerful cone-type eruption.	Aug.–Sept.	Dormant	0	0	203	One eruption following earthquake.
							Oct.–Dec.	3 to 4 eruptions weekly.	NM	150–180	----------	Rejuvenation and marked increase in activity from October to December.
Cascade	Dormant	0	0	186	186	No known activity in more than 40 years.	Aug.–Sept.	20–60 min	400 (approximate)	20–30	200	Marked rejuvenation by earthquake; dormant since Sept. 11.
Plume	60–70 min	[1] 50	20–25	195	197	Cyclic, active since 1942	Aug.–Dec.	42–46 min	[1] 50	20–25	201	New spring flowing into crater slows activity; when checked, interval shows increase noted.
North Anemone	Every 9 to 11 min.	[1] 20	3	197	198	Erupting water drained into north vent.	do	Infrequent	[1] 25	3	198	Most of energy shifted to South Anemone vent.
South Anemone	do	[1] 1.5	1.5	197	197	Chain action, eruption followed North Anemone.	do	Almost constant.	[1] 2	2	197	Chain action in Anemone group has not been characteristic since quake.
Old Faithful	61.8 min	[1] 2,750	130	200	200	Average 61.8 min (based on check of 1,158 eruption intervals between May 1 and Aug. 18, 1959).	Aug.	62.1 for 175 intervals.	[1] 2,750	130	200	There has been a somewhat steady increase in length of interval since quake. No observations for length of interval were made in November.
							Sept.	65.0 for 239 intervals.	----------	----------	----------	
							Oct.	66.8 for 47 intervals.	----------	----------	----------	
							Dec.	67.4 for 255 intervals.	----------	----------	----------	
Cascade Group:												
Hillside	1–2 hrs	[1] 200	2–3	200	200	Was in minor eruption cycle.	Aug.–Sept.	20 min–1 hr	[1] 1,300	20–30	202	Earthquake initiated major eruption cycle.
Cauliflower	50 min	[1] 63	1	192	190	Quite regular	Aug.–Dec.	50–60 min	[1] 63	1	192	Eruption a rolling boil; murky after earthquake.
Sapphire Group:												
Black Pearl	Dormant	0	0	199	199	Cyclic	do	Steady	0	3	200	Ebbed 12 in.; steady boiling.
Shell	Irregular	[1] 4.5	1	198	198	Boiling-type eruption	do	2–50 min	[1] 4.5	1	202	Most of the water flows back into crater.
MIDWAY GEYSER BASIN												
Excelsior Group:												
Excelsior	Dormant	3,600	0	199	199	Large steady discharge	do	None	3,600	0	199	Muddy first few days after earthquake.

See footnote at end of table.

TABLE 1.—*Summary of characteristics of geysers affected by Hebgen Lake earthquake*—Continued (Marler, 1964)

[U, undetermined; NM, not readily measurable; PF, periodic flow]

Name	Observations prior to Aug. 17, 1959						Observations after Aug. 17, 1959					
	Eruption frequency	Discharge 1959 (gpm)	Normal height of eruption (ft)	Temperature (° F) September 1951	Temperature (° F) Summers 1958–59	Characteristics	Date	Eruption frequency	Discharge (gpm)	Normal height of eruption (ft)	Temperature (° F) September 1959	Characteristics
LOWER GEYSER BASIN												
Great Fountain Group:												
Great Fountain	12 hrs	U	100	202	202	Eruption readily predictable.	Aug.–Dec.	3–9 hrs	U	100	203	Change in preeruption symptoms; more frequent activity.
White Dome	15–90 min	U	20–25	199	199	Shift in pattern of length of interval.	Aug. 17–21	Dormant	0	0	199	Dormant first 3 days after quake; then resumed normal function.
							Aug. 21–Dec.	15–60 min	U	20–25		
Pink Cone Group:												
Pink Cone	2–3 times weekly.	[1] 35	12–15	200	200	Jet-type eruption	Aug.–Dec.	1–4 hrs	[1] 35	12–15	201	Tremendous increase in activity.
Bead	32–33 min	[1] 45	15	182	183	Very regular	Aug.–Sept.	55–60 min	[1] 45	15	177	Longer interval; shortened to 15 or 16 min after September.
							Oct.–Dec.	15–16 min	[1] 45	15		
Narcissus	4–5 hrs	[1] 80	12	171	171	Easy to predict	Aug.–Dec.	5–6 hrs	[1] 80	12	168	Slightly longer interval.
Firehole Lake Group: Artesia.	Dormant	0	0	200	200	Cyclic	Aug.–Oct.	Steady	50	3	201	Rejuvenated by earthquake; ceased in October, but steady flow continued.
Fountain Group:												
Jelly	Irregular	[1] 81	2–10	193	192	Different types of eruptions.	Aug.–Dec.	Nearly steady first few days.	[1] 81	10–15	193	Increased frequency and vigor of activity.
Spasm	30 min to 2 hrs.	U	20–30	196	196	Two types of activity	Aug.–Sept.	30 min–1 hr	U	20–30	200	Eruptions accompanied by pronounced steam phase never observed before.
							Sept. 10–Dec.	Dormant	0	0	0	Crater emptied and stayed empty.
Bellefontaine	Dormant	0	0	198	198	Splash-type eruption	Aug.–Dec.	30 min–1 hr	25	5–6	200	Rejuvenated by earthquake.
Fountain	2 eruptions in 1959.	U		157	159	Fountain type eruption; duration 45 min.	Aug. 18	All day	U	20–50	159	Played in concert with Morning and Clepsydra; no such previous record.
							Aug. 19–Dec.	Dormant	0	0		
Morning	1–2 eruptions weekly.	170	50–150	189	188	Powerful fountain-type eruption.	Aug. 18–31	Almost constant.	170	50–150	193	Activity started by quake; dormant since Sept. 1, with steady overflow.
Clepsydra	1–2 wild-phase eruptions weekly.	[1] 150		198	196	Activity initiated by Morning.	Aug.–Dec.	Constant	200	20–30	201	Wild phase initiated by earthquake; has not ceased playing (January 1960).
Sub	Dormant	0	0	184	188	Nearly empty crater	do	Steady	12	0	196	Has not ceased playing (January 1960).
Jet	4–5 min when in active period.	[1] 25	10–15	198	199	Jet-type eruption	do	5–12 min	[1] 25	10–15	199	Action less frequent since Morning and Fountain ceased playing.
Hotel Group: Thud	Dormant	0	0	180	180	Cyclic, infrequent	Aug. 18	None	0	12–15	183	Erupted following quake; dormant since; murky.
Total of maximum rates observed.		14,400							16,000			
Average temperatures.				193.8	192.8						195.1	

[1] In eruption.

APPENDIX B

Summary of Characteristics of Springs and Pools affected by Hebgen Lake Earthquake

Marler, 1964

TABLE 2 —*Summary of characteristics of springs and pools affected by Hebgen Lake earthquake* (Maler, 1964)

[U, undetermined; NF, no flow since quake; I, infrequent; PU, periodic, undetermined; NM, not readily measurable]

Name	Observations prior to August 17, 1959						Observations after August 17, 1959					
	Eruption frequency	Discharge, 1959 (gpm)	Normal height of eruption (ft)	Temperature (° F) September 1951	Temperature (° F) Summers 1958–59	Characteristics	Date	Eruption frequency	Discharge (gpm)	Normal height of eruption (ft)	Temperature (° F) September 1959	Characteristics
UPPER GEYSER BASIN												
Morning Glory Group:												
Morning Glory Pool.		25		169	163	Steady overflow	Aug.–Dec.		0		169	Murky first few days, water 2 to 6 in. below rim of crater.
Spiteful Spring		1.3		198	199		do		1.5		200	Murky first few days.
Grotto Group:												
Bottomless Pit		U		140	195	Discharges into Chain Lake; sudden temperature increase in July.	do		U		198	Discharges into Chain Lake; murky; increase in temperature.
Square Spring		0		201	199	Active geyser in 1950	do		0		200	Murky first few days.
No. 7 Grotto Group.		5		177	175	Steady overflow	do		16		184	Increase in temperature and overflow.
Giant Group:												
South Purple Pool.		15		140	145	Algal-lined pool	do		0		182	Murky first few days, sharp increase in temperature.
East Purple Pool.		5		196	196	Ebbs 3 ft following Giant's eruptions.	do		NF		196	Murky first few days.
North Purple Pool.		0		196	197	do	do		0		197	Do.
Chromatic Spring		0		171	164	Exchange of flow with Beauty Pool.	do		0		164	One-inch ebb following quake.
Beauty Pool		30		161	164	Exchange of flow with Chromatic.	do		58		169	Increase in flow and temperature.
Inkwell Spring		20		200	200	Steady boiling	do		22		201	Increase in boiling and temperature.
Daisy Group:												
Bonita Pool		I		140	104	Ebbs with eruptions of Daisy and Splendid.	do		0		105	No overflow since quake; usual level −3 in.
Brilliant Pool	Erupts following Splendid.	PU	3–20	194	194	Ebbs 1 ft following Daisy's activity.	do		0		203	Ebbed 1 to 3 ft; boiling most of the time.
Punch Bowl Spring		3.3		201	201	Steady boiling	do		3.8		202	Increased temperature and boiling.
Black Sand Basin:												
Black Sand Pool		95		197	197	Clear, deep blue	do	4–6 min	117	1, surge	200	Geyser activity, plus increased temperature.
Green Spring	Cyclic	125	3	159	177	Periodic variation in temperature.	do		125		179	Murky first few days.
Emerald Pool		10		155	147	Bowl lined with yellow algae.	do		10		150	Do.
Handkerchief Pool.		0	3–4	176	177	Occasional eruptive activity.	do		0		165	3-in. ebb following quake.
Rainbow Pool	Cyclic	U	20–100	166	166	Occasional seasonal eruptions.	do		0		163	6-in. ebb following quake; murky.
Sunset Lake		NM		185	183	Heavy overflow color rings.	do		Heavy		190	Eruption following quake, not observed, murky several days.
Myriad Group:												
North Three Sisters.	Cyclic	15	0	181	182	Shift of activity in main bowl.	Aug.–Nov.	18–20 min	0	15–20	198	Murky, 3-ft ebb.
							Dec.	18–20 min	0	15–20		Jet-type activity.
Middle Three Sisters.		U		171	171	Constant level; flowed into North Bowl.	Aug. 17–31		0		185	3-ft ebb, murky.
							Sept.	Occasional	U	15	199	Sudden heavy surge into eruption.
							Oct.–Dec.		0			3-ft ebb.
South Three Sisters.		U		183	183	do	Aug. 17–31		0	0	185	Active through September.
							Sept.	Occasional	U	15		
							Oct.–Dec.		0	0		
Orange Spring Group:												
Orange Spring	Cyclic	0	0	138	139	Eruptions frequent when in active cycle.	Aug.–Dec.	Near constant spouting.	U	3	180	Active cycle following quake.
No. 22		Seep		137	137	Slight steady flow	Aug.–Nov.		0		141	6-in. ebb; murky first few days.
							Dec.		0			2-in. ebb.

TABLE 2.—*Summary of characteristics of springs and pools affected by Hebgen Lake earthquake*—Continued (Maler, 1964)

Name	Observations prior to August 17, 1959						Observations after August 17, 1959					
	Eruption frequency	Discharge, 1959 (gpm)	Normal height of eruption (ft)	Temperature (° F) September 1951	Temperature (° F) Summers 1958–59	Characteristics	Date	Eruption frequency	Discharge (gpm)	Normal height of eruption (ft)	Temperature (° F) September 1959	Characteristics
UPPER GEYSER BASIN—Con.												
Round Spring Group:												
Round Spring		0		178	137	No flow in 1959 preceding quake.	Aug.–Dec.		0		142	Increase in temperature plus 4-in. rise in water level from mid-1959 level.
North Round Spring.		0		151	150	Infrequent overflow	do		0		165	Same as Round Spring.
Pear Spring		0		166	165	Algal-lined spring	Aug.–Dec.		0		194	Erupted following quake.
West Round Spring.		0		142	142	Lined with brown algae	do		0		160	Erupted violently following quake.
Castle Group:												
Castle Group No. 26.		0		199	199	Steady boiling, no overflow.	do		0		200	Murky first few days; steady boiling.
Crested Pool	Rare	15	3	200	200	Normally steadily flowing spring.	do		0		155	Water level −12 in.; large drop in temperature.
Chimney Fumarole.		0		200	200	Steady steam vent	Aug.–Dec.		0 10		200 200	Steam vent steady with development of new spring on side of chimney.
South Scalloped Spring.		0		198	198	3-in. ebb below rim	do		5		202	Increase in temperature and discharge.
Scalloped Spring		0		200	198	34-in. ebb in crater	do		0		201	24 in. ebb, and increase in temperature.
Frog Spring		0		64	64	Frogs in spring	do		2.3	U	196	Erupted following quake; has remained hot with overflow.
Liberty Pool		Seep		132	133	Pool lined with brown algae.	do		.9		163	One known eruption following quake; big increase in temperature.
Oval Spring		0		199	199	1-ft ebb in water level	do		0		201	Erupted following quake.
Belgian Pool		0		164	163	do	do		0		161	Murky, ebb 18 in.
Terra Cotta Spring.	Cyclic	2	0	196	196	Dormant before quake	do	U	15	6–8	197	Active cycle initiated by quake
Grand Group:												
Wave Spring		5		131	134	Steady overflow	do		12.6		163	Erupted following earthquake; hotter with increased flow.
Calida Spring		0		183	183	1-in. ebb below rim	do		1		192	Murky plus overflow, increase in temperature.
Witches Cauldron		80		200	200	Steady boiling overflow	do		80		200	Murky water, only observed effect.
Milk Cauldron		0		190	194	28-in. ebb in crater	do		0		200	Increase in temperature and boiling plus 20 in. ebb.
Geyser Hill Group:												
Teakettle Spring		0		199	199	1-ft ebb; crater empties when Giantess plays.	do		0		203	Increase in temperature and ebb 30 in.
Rock Pool		Seep		198	198	Constant level, clear water	do		0		198	4 in. ebb plus murky water.
Dragon Spring		5		198	198	Steadily flowing spring	do		0		200	Erupted following quake; water then stayed at 35 in. ebb.
West Doublet Pool.		20–40		178	180	Increased flow with East Doublet surge.	do		20–40		193	Murky following quake, increase in temperature.
East Doublet Pool.		U		193	193	Surge about every 5 min; flowed into West Doublet.	do		U		196	Murky following quake; increase in temperature; flowed into West Doublet.
Beach Spring	U	1.5	1–3	178	185	Cyclic in activity	do	Several daily	1.5	1–3	201	Increase in temperature and frequency.
Ear Spring		30		200	200	Superheated	do	Rare	[1] 125	1	202	Erupted following quake; increase in temperature.
West Goggle Spring.	Intermittent	4	Quiet overflow.	196	196	Periodic overflow	do	Overflow every 20 to 30 min.	4–5	Surge	200	Increased temperature and overflow.
Heart Spring		5		200	199	Steady flow	do		0		200	Murky, ebb 1 in. below overflow.
Arrowhead Spring.		0		177	175	Water 4 in. below rim	Aug.–Sept.	30 min.–1 hr	[1] 54	3	200	Became eruptive following quake.
							Oct.–Dec.		1.5			Overflow but not eruptive.
Old Faithful Group:												
Chinaman Spring		.5		200	200	Constant boiling	Aug.–Dec.		.5	20–30	201	Erupted following quake.
East Chinaman Spring.		.3		196	196	do	do		.3		198	Murky; increased temperature.
Blue Star Spring		7		184	185	Clear, shelved spring	do		7		186	Murky following quake.

Table 2 (Marler, 1964)

Cascade Group:												
Gem Pool		85		188	189	Blue, constant level	do		88		194	Murky; increase in temperature.
Sprite Pool		0		167	164	Water 2 in. below rim	do		.8		181	Murky; discharge; increased temperature.
Calthos Spring		0		184	184	Water 6 in. below rim	Aug.–Nov.		0		195	Erupted following quake; became hotter in Dec.
							Dec.	2 known eruptions.	100	U		
Pulcher Spring		0		199	199	Water level 3 ft below rim.	Aug.–Oct.		150		201	Murky, overflowing.
							Nov.–Dec.		0			Water 6 in. below rim.
Mirror Pool		22		183	183	Constant overflow	Nov.–Dec.		24		184	Murky following quake.
Sapphire Group:												
Black Opal Spring		175		172	172	Erupts on rare occasions	Aug.–Dec.		175 (approximate).		173	Has stayed murky since quake.
Sapphire Pool	15 min	75 (approximate).	3–6	202	202	Deep blue color: true geyser, superheated.	Aug. 17–Sept. 4.		125	6–8	204	Constant surging.
							Sept. 5–13	2 hrs	[1] 2,250	100–150	204	Major geyser activity.
							Sept. 13–28		125	6–8	204	Constant surging.
							Sept. 29–Dec.	30 min–2 hrs	[1] 1,000–3,000	60–150	204	Major geyser activity.
West Mustard Spring.		0		164	163	Pool lined with yellow algae.	Aug.–Dec.		U	3	200	Constant spouter following quake; loss by splashing.
East Mustard Spring.		0		136	157	do	do		U	3	200	Do.
Avoca Spring		3		198	198	Constant boiling	do		0		202	Water −4 ft.; steam vent activity.
MIDWAY GEYSER BASIN												
Midway Geyser Basin Group:												
Indigo Spring		90		199	199	Steady flowing	do		0		201	Murky; ebb 18 in. below overflow.
Grand Prismatic Spring.		U				do	do		U			Ebbed 8 ft. first few hrs. following quake; crater slightly tilted to NE.
Opal Spring		0		162	162	Infrequent eruptions	do		0		180	Murky, hotter.
Turquoise Pool		0		54	54	Filled by overflow from Prismatic.	do		0		132	8 ft. ebb; increase in temperature; murky.
LOWER GEYSER BASIN												
Great Fountain Group:												
Lemon Spring		2.2		147	143	Algal-lined pool	do		2.2		137	Murky following quake.
Broken Egg Spring.		1		151	152	Constant level	do		0		187	Murky, 15 in. ebb, refilled in December.
Firehole Pool		40		196	196	Constant boiling	do		40		196	Murky following quake.
Surprise Pool		25		200	200	Superheated spring	Aug.–Sept.		25		202	Murky; hotter.
							Oct.–Dec.	U	40	1		Periodically active.
Pink Cone Group:												
Shelf Spring		85		199	199	Superheated	Aug.	4 hrs	350	10–12	202	Activated by quake.
							Sept.–Dec.		85		201	No further eruptions.
Firehole Lake Group:												
Zomar Spring		800		166	166	Steady flowing spring	Aug.–Dec.		80		167	Very turbid following quake.
Black Warrior Spring.		U		195	195	do	do		0		177	Erupted following quake; ebbed 12 in.
East end Firehole Lake.		0		165	165	Flame-like ascent of gas bubbles.	do		0		174	Water murky and hotter.
East side Firehole Lake.		0		150	151	do	do		0		148	Water murky and cooler.
Fountain Group:												
Silex Spring		13		190	190	Occasional overflow	Aug.–Sept. 15	Constant	0	3–4	200	Water muddy, steady spouting; ebbed 3 ft.
							Sept. 15–Dec.		13	0	196	Crater refilled, steady overflow.
Celestine Spring		66		196	196	Steady overflow; clear blue spring.	Aug. 17–28	None	0	0	200	Water ebbed 50 inches; muddy.
							Aug. 28–Sept. 14	Constant	0	6–8	202	Steady jetting of muddy water.
							Sept. 15–Dec.		65		199	Crater refilled with steady overflow.
Fountain Paint Pot.		0		188	192	Active mud pots at south end of crater.	Aug. 17–21		0		198	Slow rise in level, mud volcano action.
							Aug. 21–28		0		200	New mud pots at north end; new fumaroles outside main crater.
							Aug. 29–Dec.		0		196	Mud volcano action subsided; new mud pots and fumaroles persisted.

See footnote at end of table.

TABLE 2 —*Summary of characteristics of springs and pools affected by Hebgen Lake earthquake*—Continued (Marler, 1964)

Name	Observations prior to August 17, 1959						Observations after August 17, 1959					
	Eruption frequency	Discharge, 1959 (gpm)	Normal height of eruption (ft)	Temperature (° F)		Characteristics	Date	Eruption frequency	Discharge (gpm)	Normal height of eruption (ft)	Temperature (° F) September 1959	Characteristics
				September 1951	Summers 1958–59							
UPPER GEYSER BASIN—Con.												
Hotel Group:												
Thud Spring (Fungoid).	----------	8.5	----------	179	179	Steady flowing spring	Aug.–Dec	----------	8.5	----------	189	Murky, erupted night of quake.
Stirrup Spring	----------	6	----------	191	190	do	do	----------	0	----------	191	Do.
Gourd Spring	----------	0	----------	158	157	Algae-lined pool	do	----------	12	----------	186	Murky, erupted night of quake; steady discharge thereafter.
Jug Spring	----------	Slight	----------	163	163	Seep overflow	do	----------	Seep	----------	161	Murky after quake.
Cliff Spring	----------	1.3	----------	197	197	Steady flow	do	----------	1.3	----------	196	Murky, erupted night of quake.
Oak Leaf Spring	----------	Seep	----------	196	196	Quiescent spring	do	----------	0	----------	196	Murky, erupted night of quake; ebbed 6 in.
Kidney Spring	25 min	[1] 12	3–4	195	198	Periodically eruptive	do	25 min	[1] 12	3–4	199	Murky following quake.
Total maximum discharge.	----------	1,250	----------	----------	----------	----------	----------	----------	1,970	----------	----------	
Average temperature.	----------	----------	----------	176.7	176.9	----------	----------	----------	----------	----------	185.57	

[1] In eruption.